A STUDY OF THE NUTRITIONAL COMPOSITION OF SELECTED CARROT VARIETIES

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ABSTRACT

A STUDY OF THE NUTRITIONAL COMPOSITION OF SELECTED CARROT VARIETIES

by

Charles Wesley Kraut

Recently interest in the nutritional value of the diet in the United States has increased greatly. The government is moving in this area with regulations requiring the nutritional labeling of processed food products. Similar labeling proposals are under consideration for fresh fruits and vegetables.

The availability of nutritional information on fresh products is lacking. The introduction of new varities and cultural practices in the past few years has rendered currently available information unreliable.

It is certain that nutritional concern will increase in the future. Thus, this study was initiated to generate information related to hybrid carrot varieties developed at Michigan State University. It was also of interest to determine future breeding possibilities by including analyses of the parent lines of the MSU hybrid varieties.

The varieties used in this study consisted of three types. The fresh market types consisted of varieties developed primarily for fresh consumption. These varieties included

Spartansweet, Spartan Fancy, Spartan Delite, Spartan Delux and Gold Pak. Two canning types were included which were developed for processing purposes. These were Spartan Bonus and Danvers. Gold Pak and Danvers varieties represented longer established varieties which could be used for comparison to the Spartan hybrid varieties. The parent lines consisted of numbered lines: MSU 872, MSU 6000, MSU 5931, and MSU 5986.

Several locations were used in production of sample roots to determine the influence of different environments. The major locations which contributed to this study were the MSU Muck Farm, near Lansing; Imlay City, Michigan; Lubbock, Texas; and Caldwell, Idaho. Additionally, sample roots were obtained from Fremont, Michigan; Grant, Michigan; Plymouth, Ohio and Zellwood, Florida.

Root analysis was accomplished for twenty-three components. These components were divided into three groups which were proximate analysis, vitamin analysis, and mineral analysis. The proximate analysis group included nitrogen, reducing sugar, total sugar, soluble solids, total solids, and pH. The vitamin group consisted of riboflavin, thiamin, niacin, ascorbic acid, total carotene and beta carotene. Mineral analysis encompassed potassium, phosphorous, sodium, calcium, magnesium, manganese, iron, copper, boron, zinc, and aluminum. Although boron and aluminum are not considered as nutrients in mammalian systems, they were included in sample assay.

This study was conducted over two growing seasons, 1972 and 1973, to determine seasonal influences.

Although some random significant differences among varieties were found, none were consistent. Virtually no significant differences were found among locations. Some trends did become evident which are of interest.

The results varied between the two growing seasons which indicated that climatic conditions and environment are very important in nutrient accumulation. From a production standpoint it would be desirable to maintain stability in root composition from year to year. Locations and varieties exhibited different levels of stability over the two growing seasons. The late planted samples from the MSU Muck Farm showed greater stability over the seasons than the other locations. Spartansweet variety, from the fresh market lines, appeared to be less consistent from season to season than the other varieties. The parent line MSU 6000 showed seasonal instability in vitamin production.

No one variety from the fresh market group stood out as being superior in accumulation of nutritional components. Variations did occur between years, locations, and varieties but no variety was consistently high in any component.

Between the canning lines, Spartan Bonus had consistently higher nutrient levels than Danvers. Among the parent lines MSU 6000 showed high values in the proximate and vitamin groups. The mineral levels of the parent lines were generally equal.

Among the locations, roots from the MSU Muck Farm were generally better than roots from the other locations for

production of nutritional components. Values were generally high in the Muck Farm samples although no preference was indicated for planting date. Early seasonal planting did show consistently low pH values in the Muck Farm samples. The Idaho location showed generally high sugar accumulations.

Analysis of variance showed that location and variety contributed greatest to variation in results within growing seasons. Variety x Location interaction effects contributed to some variation. Storage time showed little influence on results. Storage of roots, when accomplished under optimum conditions, did not greatly affect root composition for the time of storage in this study (up to 98 days).

A preliminary vitamin analysis on canned product showed that canning greatly reduces vitamin levels. The carotenes appear to be the least depleted of the vitamin components, but direct comparison of quantitative differences between fresh and canned product was not possible.

The findings of this work generally support the reports of previous researchers.

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Charles Wesley Kraut

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To my wife

Linda

for her unselfish love

and steadfast support

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INTRODUCTION

The past several years has seen a great increase in concern over the nutritional value of the diet in the United States. It is certain that with growing populations and diminishing food reserves more attention will be paid to the nutritive content of foods so that the most benefit can be gained from the food dollar.

Coinciding with nutritional concern is criticism of the food industry specifically aimed at processing and cultural practices which trim nutrients from foods or add toxicants to foods in the form of pesticide residues.

The government has reacted in this area through the Food and Drug Administration with regulations which control the level of pesticide residues allowable in foods. Other regulations have been enacted which reduce or eliminate the use of certain pesticides such as DDT. These regulations seek to reduce the environmental level of long lasting pesticides.

The governmental regulatory agencies are now moving into the area of nutrition. In an effort to make nutritional information available to the consumer, the FDA published on January 19, 1973 in the Federal Register a proposed set of regulations which would govern the labeling of nutritional components of processed fruits and vegetables (Wodicka, 1973). Similar labeling proposals are under consideration for fresh fruits and vegetables.

Nutritional labeling of fresh fruits and vegetables presents significant problems since many factors determine the level of nutrients contained in a plant. A partial list of such factors would include variety, location of growth, growing season environmental effects, cultural practices, state of maturity at the time of harvest, post harvest handling and packaging.

A fresh fruit or vegetable is generally considered to be more nutritious than a processed product of the same type. However, some nutrients are very labile and one event of mishandling in the distribution channels can lead to a significant decrease in the nutrition available to the consumer. Thus, variations in the nutritional profile of a fresh product can be quite extensive even within a single lot.

Adding to the problem of nutrition labeling of fruits and vegetables is that nutritional information is either unavailable or out-of-date. The U.S. Department of Agriculture Handbook No. 8 (Watt and Merrill, 1963) represents the best available information on nutritional composition of foods and has been found to accurately represent the average level of nutrients in most foods (Borenstein, 1973). However, the values given represent average values for all available varieties and, therefore, may be in error for a given variety. It is also possible that a new variety is in use which differs significantly in nutrient levels from the more commonly available varieties.

Another area being considered by the FDA is the regulation of the development and release of new varieties of food crops. These regulations would require that a new variety of a food crop be reviewed and cleared prior to release for inclusion on the Generally Recognized as Safe list if the level of a nutritional component were changed by more than 20% or the toxic substance composition had increased by more than 10%. Such regulations would require the accumulation of large amounts of experimental data which would extend over several growing seasons.

Thus, it was the intent of the present project to initiate data accumulation on selected carrot varieties to satisfy several areas of concern. It was the purpose of this project: (1) to determine the nutritional composition of several hybrid carrot varieties developed at Michigan State University; (2) to compare these varieties to longer established commercial varieties; (3) to determine the nutritional composition of the inbred parent lines which were used in the development of the MSU hybrids, and (4) to determine the effect of environment on the nutritional composition by growing the carrots at several locations. This information might be used in breeding research to improve the nutritional composition of new hybrid varieties.

LITERATURE REVIEW

Vitamins

Ascorbic Acid

Ascorbic acid appears to be the most easily degraded of the carrot nutrients. While other vitamins tended to remain relatively constant, Lantz (1949) noted an immediate decrease in ascorbic acid level with harvesting, followed by further gradual losses during storage.

Langley, et al. (1933) reported that rats fed 30 g of fresh carrots were protected from scurvy. Feeding the same amount of fresh cooked carrots yielded the same results. After 4 months storage, raw carrots had increased in their protective capability whereas cooked carrots showed a decided loss in availability of ascorbic acid. Lantz (1949) showed that losses of ascorbic acid during cooking varied with the method used for cooking. Exposure to air during cooking caused greater losses than cooking in a closed container under pressure. In all cases there was extraction of the vitamin into the cooking liquid.

Canning causes significant losses of ascorbic acid as noted by Langely, et al. (1933). They reported that freshly canned carrots could not alleviate scurvy symptoms in rats when the carrots were fed at the same level that fresh carrots showed protection against scurvy. Storage of the canned product resulted in still greater losses of ascorbic acid.

Lantz (1949) noted that young carrots contained higher levels of ascorbic acid than older, more mature roots. This was also found by Yamaguchi, et al. (1952).

Yamaguchi and his coworkers also noted that location of growth and varietal type affected the ascorbic acid levels. Janes (1946) found that in addition to a location effect, there was also a seasonal effect on ascorbic acid levels. Application of different levels of fertilizer did not seem to affect the level of ascorbic acid in the carrots using from one-half to one and one-half times the normal fertilizer level. High ascorbic acid levels were correlated with high dry matter content in this study.

The chemical analysis of ascorbic acid generally calls for the extraction of the vitamin into acid media followed by measurement of the reduction of 2,6-dichlorophenolindophenol dye (Loeffler and Ponting, 1942; Rubin, et al., 1945; Association of Vitamin Chemists, Inc., 1966). Ponting (1943) investigated several acids for their suitability as extractants and found metaphosphoric and oxalic acids gave the lowest losses of ascorbic acid during extraction. Ascorbic acid reduces 2,6-dichlorophenolindophenol immediately upon contact whereas other substances reduce the dye more slowly, thus rapid colorimetric readings must be obtained after dye addition. Certain circumstances call for additional precautions in analysis such as in the analysis of highly colored products (Robinson and Stotz, 1945), in the analysis of specialized products (Schmall, et al., 1953), or in the analysis of some plant materials (Freebairn, 1959; Vavich, et al., 1945).

The analysis of dehydroascorbic acid calls for more specialized procedures. Dehydroascorbic acid is generally reduced to ascorbic acid and then analyzed as ascorbic acid using 2,6-dichlorophenolindophenol dye. King (1941) used hydrogen sulfide to reduce the dehydroascorbic acid and pointed out several interfering reactions. Hughes (1956) used homocysteine as the reducing agent and described a method for its use.

Thiamin

Thiamin is not as easily destroyed as ascorbic acid. Langely, et al. (1933) reported no decrease in thiamin potency after 4 months storage when compared to fresh carrots. Cooking of the stored carrots did result in slight decreases in potency, however. The destruction of thiamin by heat is related to both the pH and the types of electrolytes present (Beadle, et al., 1943). Using several ion systems Beadle and his coworkers found that thiamin was destroyed at levels ranging from 100% in the presence of borates, down to 3% in the present of phosphates. These results were obtained by boiling thiamin in aqueous solutions for one hour at pH 5.4. When the pH was altered by 2 to 3 pH units in either direction, up to 100% destruction was noted in all systems studied.

Langley, et al. (1933) noted that freshly canned carrots had thiamin levels comparable to fresh raw carrots. Storage of the canned product for 6 months resulted in losses of the vitamin.

Yamaguchi, et al., (1952) found that thiamin was present in higher concentration in the peels of carrots. They also indicated that location of growth and variety may also affect thiamin levels.

The chemical determination of thiamin involves the oxidation of thiamin to thiochrome with alkaline potassium ferricyanide followed by extraction of the thiochrome into isobutyl alcohol for fluoresence measurement (Association of Vitamin Chemists, Inc., 1966; Hennessy, 1941; Conner and Straub, 1941a; Conner and Straub, 1941b). Clausen and Brown (1944) indicated that precautions should be taken against temperature and dissolved oxygen since these factors affected fluorescence. Alterations in the procedure are required for some products, such as cereal products (Bechtel and Hollenbeck, 1959). Moyer and Tressler (1942) reported general agreement among three assay methods used for frozen vegetables which were bioassay, thiochrome, and fermentation procedures.

Riboflavin

Riboflavin is rapidly destroyed by light (Williams and Cheldelin, 1942). The destructive effects of temperature and pH act more on the light reaction than on chemical destruction since heating riboflavin solutions in the dark resulted in no destruction. The opacity of many foods serves to protect their riboflavin content by blocking out light during cooking and handling.

As with the other nutrients, location and variety have some effect on accumulation of riboflavin in carrots (Yamaguchi, et al., 1952).

Riboflavin fluoresces green when irradiated with blue light. This serves as the basis for its chemical determination (Association of Vitamin Chemists, Inc., 1966; Hodson and Norris, 1939). The primary shortcoming of the procedure is the presence of other fluorescing substances and pigments which are extracted with riboflavin. Several methods have been developed for the removal of these interfering substances (Hodson and Norris, 1939; Conner and Straub, 1941b). Hoffer et al. (1944) and Arnold (1945) reported on methods used in assay of riboflavin in cereal products.

Emmett, et al. (1941) reported finding similar riboflavin values using fluorometric, biological rat growth, and microbiological methods.

Niacin

Niacin, which is composed of nicotinic acid and nicotinamide, is more stable than the other B-complex vitamins found in carrots (Association of Vitamin Chemists, Inc., 1966). Variety and location had some effect on the accumulation of niacin in the roots as found for the other vitamins (Yamaguchi, et al., 1952).

The basis for the chemical determination of niacin depends on the opening of the pyridine ring with cyanogen bromide. The resulting carbon chain is then combined with some aromatic amine to yield a color which can be read colorimetrically (Association of Vitamin Chemists, Inc., 1966; Waisman and Elvehjem, 1941). Various aromatic amines have

been studied and some have proven to be better than others under different situations (Martinek, et al., 1943; Steele, 1945; Melnick and Field, Jr., 1940; Teerie and Shimer, 1944).

In working with plant materials it is usually necessary to use an acid extraction media followed by digestion with an appropriate enzyme to free the niacin from its coenzyme forms (Cheldelin and Williams, 1942; Waisman and Elvehjem, 1941). Hale, et al. (1942) found that both chemical and microbiological determination of niacin gave reliable results.

Carotenes

Carrots comprise one of the cheapest and most accessible sources of provitamin A active carotenes. These carotenes occur primarily as beta-carotene and alpha-carotene in the carrot root. Since the discovery of provitamin A activity in carotenes, the study of carotenes in carrot roots has become a topic of a great deal of research. The majority of the reported investigations were aimed in one of three directions: to determine by what pathway carotenes were synthesized, to determine what factors controlled the synthesis of carotenes, or to find methods for separating and analyzing the carotenes of the carrot.

Goodwin (1965) gave a synthetic scheme for carotenoids which was documented with many research reports. He stated that carotenes are synthesized from a basic 5-carbon unit by acceptable cyclizations and rearrangements. This was further supported by Splittstoesser (1967) and Hill, et al. (1970). Blass, et al. (1959) showed that in some algae carotenes are

the primary product of synthesis with xanthophylls and carotene epoxides composing only a small part of the total. This also seems to be the case in carrot root.

Carotenes occur in all tissues but are more highly concentrated in the chloroplasts (Bonner and Varner, 1965). The carotenes of carrot roots are associated with the fatty substances of the chromoplasts of the cell and are apparently synthesized at that site (Richardson and Mayfield, 1932; Becker, 1970; Banga and DeBruyn, 1964). Roberts and Southwick (1948), using the electron microscope, indicated that carotene was more of a storage product than a functional cell entity, and that vitamin A and carotene were associated with the anabolism and catabolism of chromoplasts.

The close relationship between chlorophyll and carotene synthesis suggests that common precursors are involved. Baker and Tomes (1964) suggested phytol as the controlling factor for synthesis of both carotenes and chlorophyll. Godnev, et al. (1966) showed that carrot root does contain the mechanism for chlorophyll synthesis since chlorophylls a and b were produced in a carrot root preparation exposed to a light impulse. Thus, total conversion of pigment precursors to carotene is the normal occurrence in carrot roots.

The majority of research studies were concerned with finding the factor or set of factors which controlled carotene synthesis.

These studies led to the conclusion that numerous environmental factors interact to produce a carotene response

in the carrot root. Great variations were found to occur between growing seasons, varieties, and locations (Hansen, 1945; Janes, 1946; Brown, 1947; Booth and Dark, 1949; Yamaguchi, et al., 1952; Harper and Szcheile, 1944; Banga and DeBruyn, 1954). Certainly this would be expected when working with a biological material.

Some of the first investigations on the effect of environmental factors on color were concerned with temperature. Barnes (1936) reported that optimum color was developed at temperatures of 60 F to 70 F. Banga and DeBruyn (1964) suggested that temperatures around 20 C (68 F) favored carotene synthesis and that lower temperatures (8 C) favored protein synthesis for primary vegetative growth. Banga, et al. (1967) reported that optimum color was developed when soil temperature was below 65 F for several weeks prior to harvest. Bradley and Dyck (1968) found that low preharvest temperatures resulted in lower total carotene content but a higher beta- to alpha-carotene ratio.

Bradley and Rhodes (1969) investigated several carrot varieties that grew well above the temperature of 65 F and several other varieties that grew well below this temperature. Thus, it is shown that factors other than temperature are involved with carotene synthesis control.

In studies to determine the effect of root age on color Barnes (1936), Brown (1947), and Weckel, et al. (1962) found that color increased steadily up to about 100 days after seeding, after which there was only a slight change. Hansen

(1945) found that roots steadily increased in color up to about 140 days after which there were no significant changes.

A number of other workers including Lachman (1944), Lantz (1949), Bradley and Dyck (1968), Yamaguchi, et al. (1952), and Booth and Dark (1949) found that pigment concentration increased steadily as the root matured with no leveling off of synthesis after a period of time from seeding had elapsed. Pepkowitz, et al. (1944) reported steady increases in carotene levels up to approximately 90 days from seeding, after which the levels decreased.

Werner (1941) and Banga and DeBruyn (1954) reported that carrots reach a maximum carotene concentration and maintain that level. Banga and DeBruyn (1964) reported this to be a fluctuating maximum which was caused by the increase in carotenes in the individual cells of the ripening tissue which was increasing in the upper portion of the root. Thus, they concluded that the carotene content per unit of root weight increased with root growth and that the root matured as it grew. Maturing of carrot roots is characterized by a tendency for the root to become thickened along its length, for the root tip to become rounded, and for the pigment levels to increase. Maturity does not occur simultaneously in all parts of the root. As long as the tip of the root continues to grow, it will not be as mature as the upper portion. Consequently, the carotene content at the top of the root is always higher than the concentration at the tip of the root (Emsweller, et al. 1935).

Since different carrot varieties mature to different root sizes, some investigations were undertaken to determine if there was a correlation between root size and carotene concentration. Yamaguchi, et al. (1952) and Barnes (1936) found that large roots were slightly higher in carotene content than smaller roots of the same age. Pepkowitz, et al. (1944) found an inverse relationship between root size and carotene content with smaller roots having more carotene. Becker (1970), in reviewing other work, concluded that maximum root weight and maximum carotene content were both reached at about the same time. Thus, carotene content is more dependent on variety and maturity than on root size.

Carrott varieties differ in numerous aspects which include root size, root shape, ratios of phloem to xylem tissues, carotene levels, and reaction to environmental factors. When varietal differences are considered, genotypic differences must also be considered since the genetic makeup is the basis from which differences are derived. Miller, et al. (1934) recognized that selection and breeding of highly colored carrot varieties would lead to new varieties with improved color. Emsweller, et al. (1935) studied 18 different carrot lines which were derived from 2 original ancestors and found carotene values ranging from 32 mg/100g dry matter to 63 mg/100g dry matter.

Brown (1949) determined statistically significant differences between varieties he tested and concluded that varieties differ genetically in their mature carotene content.

Numerous workers have indicated that varietal genotype definitely affects the carotene concentration in the mature root (Bills and McDonald, 1938; Pepkowitz, et al., 1944; Yamaguchi, et al., 1952; Harper and Zscheile, 1945; Hansen, 1945; Brown, 1947; Bradley and Dyck, 1968; Dark and Booth, 1946).

Booth and Dark (1949) reported that each of the nine varieties of carrots they tested reached a different maximum total carotenoid concentration. They also noted that the maximum reached was different in the different years of the study, but the relative positions of the varieties to one another remained the same. Thus the interaction of environment and genotype ultimately determined the carotene level developed.

Modern methods of genetic investigation are now being used to determine the gene systems which control carotene synthesis (Imam and Gabelman, 1968; Laferriere and Gabelman, 1968).

It is questionable whether plan nutrition, beyond that which is required for normal plant growth, has any influence on the color development in carrot roots. Freeman and Harris (1951), Barnes (1936), Miller, et al. (1934), and Janes (1946) reported no constant or significant effects of fertilization on carrot root color. Kelly, et al. (1952) reported an increase in carotene level with additions of boron to boron deficient roots. However, when boron deficiency symptoms were eliminated, no further changes in carotene content were noted.

Michel-Wolwertz and Sironval (1963) reported that application of gibberellic acid to buds of carrot plants promoted the growth of leaves and stems but inhibited root growth and root color development.

Soil moisture has been shown to affect carrot color. Banga and DeBruyn (1964), Banga, et al. (1963), Barnes (1936), and Lantz (1949) reported that carrots grown in a low moisture soil had higher carotene levels than carrots grown in higher moisture conditions. Banga and DeBruyn (1964) explained that high soil moisture content promoted root growth which suppressed carotene synthesis, thus yielding the results noted.

Bradley, et al. (1967) indicated that irrigation increased yield but decreased color. Rygg (1949) stated that in certain areas, irrigation is withheld for several weeks prior to harvest to improve carrot color. Miller, et al. (1934) reported that a difference between 21.7% and 23.2% in soil moisture content produced differences in carrot color with the lower moisture soil yielding better color.

Planting system may play a part in carotene development. Miller, et al. (1934) noted higher color levels in carrots which were grown in a high seed bed. This system allowed for better soil drainage and aeration. Banga and DeBruyn (1964) and Banga, et al. (1958) reported that favorable root maturation occurred in soil with a soil oxygen level of greater than six percent. Banga and DeBruyn (1956) found that distance between plants effected carotene development.

The fact that a certain quantitative amount of alpha-carotene and beta-carotene occurs in carrot roots does not insure that this figure can be directly converted to units of provitamin A activity. Bio-potency is dependent on many factors which include specific structural and stereo-chemical configurations, animal differences within and between species, diet composition, and specific requirements (Ullrey, 1972).

The average level of carotenes which possess provitamin A activity in carrots has been found to be nearly 90% of the total carotenes (Booth and Dark, 1949), although values as low as 84.6% were found by Naef and Turian (1963). Some researchers have indicated that the total carotene amount could be used to determine the level of the provitamin A active carotenes since the nutritionally active components amounted to such a large part of the total (Booth and Dark, 1949; Brown, 1947; Zscheile, 1941).

Graves (1942) cautioned that no results of carotene vitamin activity should be accepted unless they were backed by biological findings. Smith and Otis (1941) found only 25% conversion of carotene value, as determined by chemical analysis, to vitamin A activity as determined in rat feeding studies. Barnes (1936) reported that bio-assay produced higher vitamin A values than could be explained by chemical analysis. He reasoned this to be due to oxidation or destruction of carotenes during extraction for chemical analysis.

Several workers have reported that carotene levels tend to increase in carrots that were stored (Lachman, 1944; Lantz, 1949). Rygg (1949) reported increases based on the original fresh weight of the carrot prior to storage. Brown (1949) and Brown (1947) reported increases based on dry weight.

Langley, et al. (1933) and Richardson and Mayfield (1932) reported that depleted rats showed good growth when fed carrots that had been stored for 4 months.

Lee and Tapley (1947) reported the root cellar storage preserved good quality in carrots. Platenius (1934) and VanDenBerg and Lentz (1966) reported that carrots should be stored in a temperature of 32-34 F with a relative humidity from 96-100%. Higher temperatures and lower relative humidities resulted in desiccation, softening, and decay.

Preservation processing of carrots causes a loss in availability of the provitamin A active carotenes. Langley, et al. (1933) and Richardson and Mayfield (1932) reported slight loss of carotenes immediately after canning, with greater losses occurring through storage. Bradley and Smittle (1965) reported great differences between fresh carrot and canned carrot color. Weckel, et al., (1962) reported that canning caused loses of provitamin A activity ranging from 7.3% to 11.7% due to isomerization.

Lantz (1949), Langley, et al. (1933), and Richardson and Mayfield (1932) reported that cooking of fresh or stored carrots caused negligible carotene losses.

The basic analytical method for carotene determination calls for extraction into an organic solvent such as ethyl

alcohol or acetone followed by transfer into hexane or petroleum ether. The extract is then chromatographed on a suitable adsorbant to separate the different carotenes for spectroscopic analysis (Association of Official Agricultural Chemists, 1965; Association of Vitamin Chemists, 1966; Bickoff, 1957).

Prior to 1941, extraction of carotenes was accomplished by grinding the material in a mortar and pestal with quartz sand and acetone washes. Moore and Ely (1941) reported a rapid quantitative extraction method using the Waring blender.

Reports of selective separation of carotenes have been available since 1934 using column chromatographic adsorption techniques (Peterson, 1941). Mackinney, et al. (1942) reported separation of carotenes using a combination of magnesium oxide and Hyflo-Supercel in column chormatography, a method still used today.

Just as vitamin A is susceptible to oxidation and light, so are the provitamin A carotenes (Wilkie, 1941). Thus, analytical procedures must guard against excessive exposure to light and air.

Ahmed and Scott (1962) and Lauber, et al. (1967) described the use of a color and color difference meter for estimating carotene levels of sweet potato roots. Weckel, et al. (1962) found that the color difference meter was not suitable for use in estimating carrot carotene levels using carrot slices. Bradley and Smittle (1965) reported using the color difference meter a/b ratio for color comparisons between processed carrot color and color judged by a subjective panel.

Sugars and Soluble Solids

As with the vitamins, the levels of sugars and soluble solids attained in a carrot root are dependent on an interaction of variety genotype and environment. Sistrunk, et al. (1967), Bradley, et al. (1967), and Hasselbring (1927) stated that starch, sugars, and soluble solids levels varied between varieties studied. Carlton and Peterson (1963) and Bradley and Smittle (1965) stated that varietal genotype was the most important factor in determining sugar levels. Hasselbring (1927) felt that environment had a greater influence over sugar development than varietal characteristics.

Platenius (1934) indicated that from 60 days of age, total sugars increased only slightly. Roots became sweeter, however, due to incorporation of glucose into sucrose. Barnes (1936) and Yamaguchi, et al. (1952) also found increased sugar levels and increased sweetness with root age.

The occurrence of starch is not generally indicated in carrots. Hasselbring (1927) did not find granular starch in the varieties he studied. He indicated that acid hydrolysis yielded from 1.25% to 1.50% increase in measurable reducing sugars due to hydrolysis of soluble dextrins and hemicelluloses. Sistrunk, et al. (1967) did indicate the presence of starch.

Plant nutrition has been shown to affect sugar levels. Barnes (1936) noted that increasing nitrogen levels produced an increase in glucose and decrease in sucrose with total sugars remaining relatively constant. Southards and Miller (1962) found that carrots grown with low nitrogen, phosphorous

potassium, or calcium produced higher total sugar levels. High magnesium also produced high sugar levels. Harris (1943) found that addition of boron, copper, and manganese to carrots grown in peat or sandy soils decreased sugar levels. In clay soils the addition of boron and zinc increased sugar levels.

High soil moisture conditions have been found to decrease sugar levels (Bradley and Smittle, 1965; Bradley, et. al., 1967; Sistrunk, et al., 1967). This was probably due to water uptake since soluble solids and sugars tended to be higher during dry weather.

Hasselbring (1927) reported that storage caused two changes to occur in carrots. First, sucrose was converted to reducing sugars with proportional changes occurring in the levels of each. Second, polysaccharides were transformed to simple sugars. Rygg (1945) reported that fructose occurred in quantities approaching one-half of the total reducing sugars present. Previous to this it was believed that carrot root contained only sucrose and glucose. Riddle and MacGillivray (1966) reported increased soluble solids in stored carrots. Hasselbring (1927) stated that carbohydrate transformations occurred at a much slower rate at 32-35 F than at 39-40 F. At the cooler temperature 28% of the sucrose was lost in the first ten weeks of storage compared to 43% at the higher temperature.

Bradley and Smittle (1965), Bradley, et al. (1967) and Riddle and MacGillivray (1966) all noted a correlation

between soluble solids and total solids in carrot roots. Riddle and MacGillivray (1966) reported that increased soluble solids resulted in increased total solids. Carlton and Peterson (1963) found a positive correlation between soluble solids and total sugars.

Total Solids

The total solids content of carrot roots is affected by variety, location of growth, and environmental factors (Yamaguchi, et al., 1952; Janes, 1946). Werner (1941) noted an increase in total solids to a maximum followed by decreased levels over the growing season. Barnes (1936) observed steadily increasing levels over the test period of 58 to 142 days. Both Werner and Barnes noted that the xylem (core) was lower in total solids than the phloem (cortex).

Bradley and Smittle (1956) and Bradley, et al. (1967) noted that planting date and harvest sequence markedly affected total solids levels. Late winter plantings seemed to be higher in solids than summer plantings. They reasoned this to be due to temperature and day length changes in the late growing season.

Carleton and Peterson (1963) found that total solids were correlated to total sugars. Riddle and MacGillivray (1966) observed that increases in total solids resulted in like increases in soluble solids. They also noted that the upper one-third of the carrot root was higher in total solids than the middle or bottom third.

Barnes (1936) and Riddle and MacGillivray (1966) indicated that low soil moisture conditions resulted in higher total solids in the carrots.

Janes (1946) found a correlation between high ascorbic acid content and high total solids.

Nitrogen and Minerals

There has been very little work accomplished on the mineral or nitrogen content of carrot root. Several reports, already cited under other headings, dealt with the response of micro-element additions to the growing media on other quality parameters such as yield, total sugars, total solids, and carotenes (Harris, 1943; Kelly, et al., 1952; Southard and Miller, 1962).

Platenius (1934) noted that stored carrots underwent slow hydrolysis of proteins with no apparent effect on quality. Yamaguchi, et al. (1952) found that carrots harvested during the winter months appeared to be slightly higher in protein.

Yamaguchi, et al. (1952) studied the effects of several factors on the composition of carrot roots. They analyzed for numerous components which included protein, calcium, iron, and phosphorous. In addition to higher protein in winter harvested roots, they also noted higher iron and lower calcium levels. The total carrot composition was affected by both location of growth and variety.

MATERIALS AND METHODS

Raw Material

The fresh material used in this study consisted of several varieties and hybrids of carrot roots Daucus carota L. The roots were obtained from experimental plots and from roots grown for commercial production. The roots were harvested randomly to provide a representation of the plots in the sample. Each sample was comprised of 20 or more typical roots of the variety.

Raw product was obtained from locations within Michigan which included the MSU Muck Farm, Imlay City, Fremont, and Grant, plus one location each in Texas, Idaho, Florida, and Ohio. Twelve separate carrot lines were investigated which could be divided into three groups: fresh market varieties, canning varieties, and parental lines. The fresh market varieties included Spartansweet, Spartan Fancy, Spartan Delite, Spartan Delux, and Gold Pak. The canning varieties included Spartan Bonus and Danvers. The Gold Pak and Danvers varieties were used as check varieties to serve as a basis for comparing the other varieties, which were developed at Michigan State University.

The parent lines used consisted of inbred numbered lines: MSU 872, MSU 5931, MSU 6000, MSU 9541, and MSU 5986. The parent lines were inbred lines developed at Michigan State University to serve as stable bases from which breeding could

be accomplished. All of the Spartan named varieties used in this study were derived from crossbreeding using the above parent lines.

The pedigrees of the Spartan varieties are given below:

Spartansweet = MSU 5931 x 6000
Spartan Fancy = MSU (5931 x 5986) 6000
Spartan Delite = MSU (5931 x 6000) 5986
Spartan Delux = MSU (872 x 5931) 6000
Spartan Bonus = MSU (872 x 5931) 9541

The harvested roots were placed in perforated bags and transported to the Food Science Building, Michigan State University for storage and analysis. All roots were washed before being placed in storage to extend storage life. The roots were stored in a controlled temperature cubicle maintained at 33 F until analysis. Storage time was kept at a minimum so that assays would reflect nutrient levels in the freshly harvested roots as closely as possible.

Sample Handling

Samples were held in the storage cubicle until the time of analysis. Upon removal from storage for analysis, each bagged sample was divided in half to produce two subsamples. This was done either by count if the sample was small, or by approximate weight if the sample was large. In both cases, the division was made with no regard to selection of roots for either sample, thus the randomness of the field harvest was maintained in the subsamples.

Assay samples were obtained by cutting a one inch slice from the center of the length of each root. When sample size

permitted, only one slice was taken per root. Small sample sizes necessitated taking up to three inches of a given root at times. Under these circumstances the slices were obtained from as close to the center section of the root as possible. At no time was either the top or the bottom of a root included in the sample as these sections represent widely divergent levels of nutrients. (Banga and DeBruyn, 1964; Becker, 1970).

The pooled one inch cuts were then further reduced to approximately 2 mm slices by slicing them on an electric meat slicer. These slices were then mixed and assay samples were weighed from them.

Two methods were used in obtaining assay samples. For certain of the analyses, slices were weighed directly as assay samples. The second method involved the creation of a slurry from which aliquots were taken. Slices were weighed directly for assay of total solids and ascorbic acid (Vitamin C). The slurry was used to obtain samples for thiamin, riboflavin, niacin, carotenes, sugars, pH, and soluble solids. Nitrogen and mineral samples were obtained from the dried total solids samples.

The slurry was made by combining 100g of carrot slices with 200 ml of distilled water in a Waring blender jar. The mixture was then blended at high speed for three minutes. The blended mixture was maintained at a slow blender speed while weighing of samples was accomplished to minimize separation of the carrot particles from the liquid phase.

Samples were removed from the blender jar with the use of an inverted pipet. This method could be effectively used by carefully sliding the pipet down the side of the jar to avoid contact with the blades.

Miscellaneous Analyses

Nitrogen

Nitrogen content was determined on dried and ground samples of carrot slices (see Total Solids). Analysis was carried out on 0.5 g samples using the Kjeldahl Method (AOAC, 1965). Because of mercury toxicity a combination of K_2SO_4 and $CuSO_4$ was used as the catalyst for digestion in place of mercuric oxide and potassium sulfate as outlined in the method.

pH

A relative pH of the carrot samples was obtained by determining a pH of the carrot-water slurry. This was accomplished by inserting an electrode into the slurry and reading the pH meter deflection. A Beckman Zeromatic pH Meter was used. (Beckman Instruments, Inc., Fullerton, California).

Total Solids

Twenty-five grams of freshly cut carrot slices were weighed into tared aluminum moisture dishes and placed into a forced air oven maintained at 75 C. The samples were held in the oven overnight (about 22 hours), before removal to a desiccator for cooling and subsequent weighing.

The dried slices were then ground to pass a 20 mesh sieve using a Wiley Mill (Arthur H. Thomas Co., Philadelphia, Pa.). The ground samples were held in tightly capped glass jars for nitrogen and mineral analyses.

Soluble Solids

Adequate carrot-water slurry was filtered through Whatman No. 1 filter paper to provide a sample for soluble solids determination. Soluble solids were then read on a Abbe Refractometer, Precision Model, manufactured by Valentine & Co., Vista, California. The value obtained was not a true value since the slurry reduced the actual soluble solids level of the raw carrot. The refractometer values were multiplied by three to adjust them back to the raw carrot level since the slurry contained one-third fresh carrot by weight.

Mineral Elements

Potassium

Potassium was determined using 0.25 g of the ground total solids sample. The sample for potassium analysis was weighed into a glass jar followed by 50 ml of distilled water. The jar was capped and agitated periodically for 2 hours. The sample was then filtered through a coarse paper (Whatman No. 1).

The water extract was used for potassium analysis. Flame photometry was used for the determination on a Beckman Model B Flame Photometer (Beckman Instruments, Inc.,

Fullerton, California) adjusted to 755 nm. The instrument was adjusted to read 100% T using a solution of 400 ppm potassium. The results were obtained by comparison to a standard curve (Figure 1).

Remaining Minerals

Phosphorus, sodium, calcium, magnesium, manganese, iron, copper, boron, zinc, and aluminum were determined using an Applied Research Laboratory Quantograph (Applied Research Laboratory, Division of Bausch and Lomb, Glendale, California).

Mineral analysis was carried out on 0.5 g of sample weighed from the ground total solids sample. The sample was weighed into a crucible and ashed at 500 C for at least 8 hours. The ash was then dissolved in a nitric acid solution in preparation for spectrograph analysis.

The analysis itself was an atomic emission type procedure in which the sample was introduced into a high voltage electrical spark which excited the elemental atoms. The emission spectra were then recorded at specified wavelengths for each element. Levels of the elements in the sample were then determined by comparison to standard curves.

Boron and aluminum were included in analysis but are not considered to be nutrients in mammalian systems.

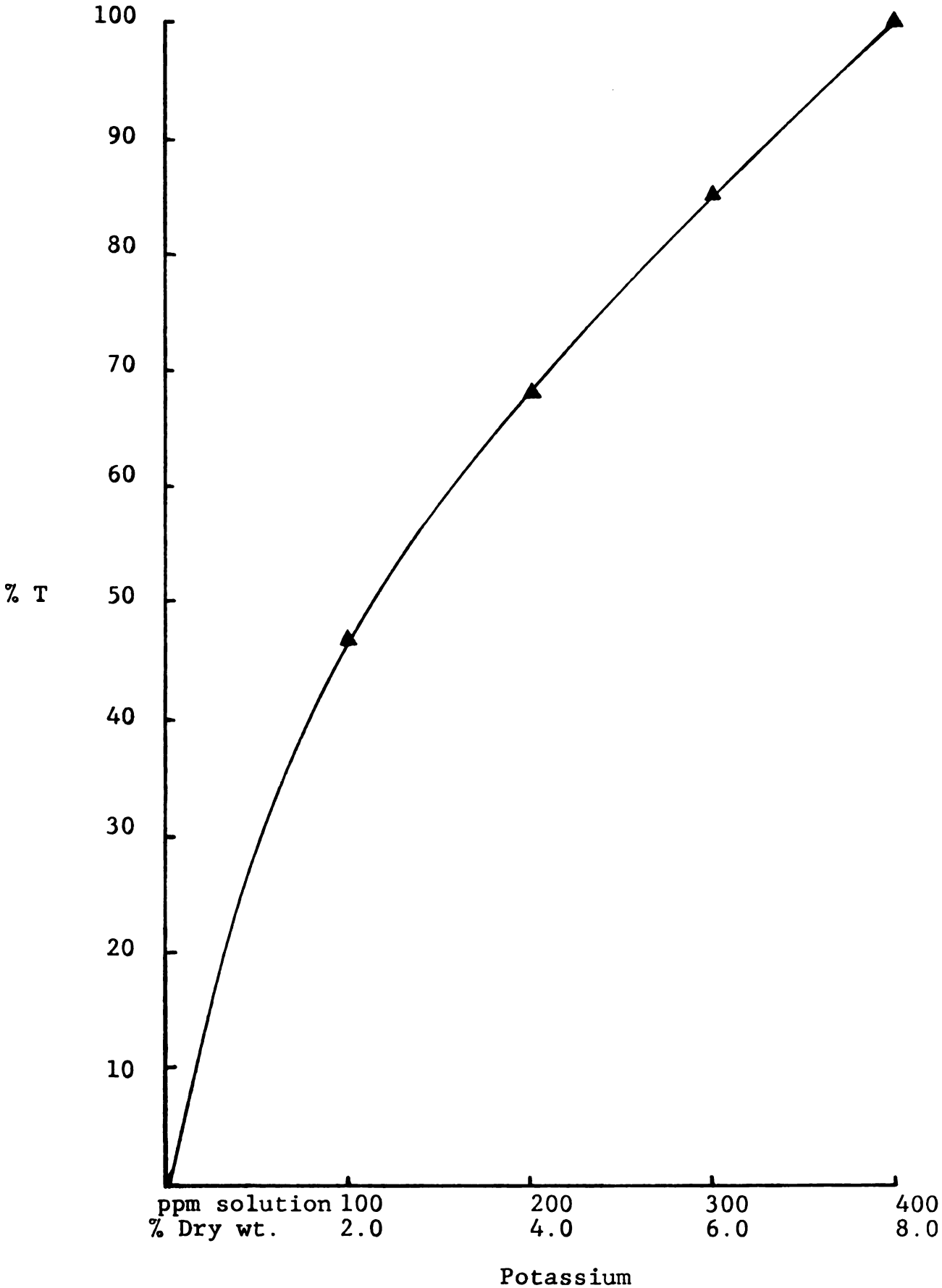

Figure 1. Standard Curve for Potassium Analysis

Vitamins

Extraction of Thiamin, Riboflavin, and Niacin

Seventy-five grams of the carrot-water slurry were weighed into a 400 ml beaker. Sixty-five milliliters of 2.5N HCl were added and mixed. The beaker was covered with aluminum foil and held in a boiling water bath for 30 minutes with occasional swirling. After this digestion, the beaker was placed in a 35 F refrigerator to cool.

When cool, the digest was adjusted to pH 4.5 with sodium hydroxide and sodium acetate using a pH meter. The digest was adjusted to about pH 4.0 with 10N sodium hydroxide and then to pH 4.5 with 2.5 Molar sodium acetate. At no time was the pH allowed to rise above 6.0 since riboflavin is very unstable in alkaline solutions (Association of Vitamin Chemists, 1966).

The digest was then quantitatively transferred to a 200 ml volumetric flask which contained several milligrams of fungal pectinase (Nutritional Biochemicals Corp.). The flasks were swirled and allowed to incubate at room temperature (70 F) for three to four hours or in a 35 F refrigerator overnight.

After incubation, the flasks were made to volume with distilled water and filtered through Whatman No. 5 filter-paper into brown glass bottles. This extract was stored under refrigeration and was subsequently used for analysis of thiamin, riboflavin, and niacin.

All of the above steps were carried out under reduced light as both thiamin and riboflavin are destroyed by visible light

Assay for thiamin, riboflavin and niacin was carried out using Technicon AutoAnalyzer* systems.

Thiamin

The previously prepared vitamin extract was reasonably free of interfering substances. However, in the case of thiamin, a certain amount of fluorescing material remained which had to be removed before assay could be accomplished on the automated system. This material was effectively removed by a single extraction in isobutyl alcohol.

A sample of vitamin extract was added to twice its volume of isobutyl alcohol in a suitable size separatory funnel. The mixture was then shaken for two minutes and allowed to separate for at least 30 minutes. The lower aqueous layer was used for thiamin analysis. This procedure was carried out under reduced light.

The automated procedure used was a modified Auto-Analyzer II Industrial Method No. 143-71A (Technicon Corp., 1971). This method is basically an automation of currently available thiochrome methods (AOAC, 1965; Association of Vitamin Chemists, Inc., 1966). Thiamin was oxidized to thiochrome with alkaline potassium ferricyanide. The

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*Trademark for Technicon Industrial Systems, Tarrytown, New York. A division of Technicon Instruments Corp., Tarrytown, New York.

thiochrome was then extracted into isobutyl alcohol and the fluorescence of this extract was measured at 436 nm (Kirk, 1973).

Known standard thiamin solutions were run at the same time as the sample runs. Thus, unknown thiamin levels were determined by comparison to standard curves. The standard thiamin solutions used ranged from 0.1 ug/ml to 0.5 ug/ml in increments of 0.1 ug/ml.

Riboflavin

The previously prepared vitamin extract was unsuitable for determination of riboflavin without further purification. High levels of substances which interfered with riboflavin assay were present. These substances were removed by oxidation with potassium permanganate following the procedure outlined in Methods of Vitamin Assay (Association of Vitamin Chemists, Inc., 1966).

Ten milliliters of extract were placed into a test tube. To this was added a drop of concentrated HCl followed by 0.5 ml of 3% $KMnO_4$. The contents were mixed and allowed to stand for exactly 2 minutes. After 2 minutes, 0.5 ml of 3% H_2O_2 was added and mixed. The red color disappeared within 10 seconds. This solution was then ready for automated analysis.

The automated procedure used was a modified Auto-Analyzer II Industrial Method No. 140-71P (Technicon Instruments Corp., 1971). The sample was pumped into the machine and dialyzed against dilute sodium chloride before

the fluorescence of the sample was measured. The sample was excited with 436 nm light. The fluorescence was measured at 510 nm. Sample blanks were measured by quenching fluorescence with $Na_2S_2O_4$. (Kirk, 1973).

As with thiamin, known solutions of riboflavin were run at the same time so that unknown levels could be determined by comparison to a standard curve. The riboflavin standards used ranged from 0.05 ug/ml to 0.4 ug/ml.

Niacin

No further purification of the vitamin extract was required for automated analysis of niacin.

The automated method used for niacin assay was an adaptation of available methods using cyanogen bromide. (Kirk, 1973). Niacin reacts with cyanogen bromide to yield a pyridinium compound which then undergoes rearrangement. The derivatives thus formed will couple with aromatic amines to give colored compounds that can be measured colorimetrically. (Association of Vitamin Chemists, Inc., 1966). Sulfanilic acid provided the source of aromatic amines in this procedure. Color was recorded as %T at 470 nm.

Known niacin standard solutions were run with each sample set to provide a standard curve for determination of unknown levels. The standard niacin solutions used ranged from 0.4 ug/ml to 1.0 ug/ml.

Ascorbic Acid

Ascorbic acid was determined using a modification of the method reported by Loeffler and Ponting (1942). These workers

used a 1% solution of metaphosphoric acid as the extracting media. Ponting (1943) later reported that both metaphosphoric acid and oxalic acid provided equal recovery of ascorbic acid from the systems under study. In addition, the oxalic acid extracting solution was more stable than the metaphosphoric acid solution. Therefore, in this study a 0.5% oxalic acid solution was substituted for the 1% metaphosphoric acid solution as an exacting media.

The basis for the method involves the oxidation of ascorbic acid with the dye 2,6-dichlorophenolindophenol. Thus, a standardized working dye solution was prepared prior to each set of analyses from a stock dye solution. The stock dye solution was prepared by dissolving 100 mg of sodium 2,6-dichorophenolindophenol in approximately 50 ml of boiled distilled water. The solution was then filtered through Whatman No. 2 filter paper into a 125 ml Erlenmeyer flask. The filter paper and the container used for dissolving the dye were washed with another 50 ml of the boiled distilled water. The wash was combined with the filtered dye solution, stoppered, and stored under refrigeration until used. This stock dye solution was stable for 2 to 3 weeks. The boiled distilled water used to prepare the stock dye solution contained 80 mg/l sodium bicarbonate. The distilled water used was boiled to expel any dissolved carbon dioxide and the sodium bicarbonate added to aid in maintaining a carbon dioxide free status.

The working dye solution was prepared by diluting approximately 7 ml of the stock dye solution to 500 ml with boiled distilled water (bicarbonate free). The working dye solution was then standardized using a Bausch and Lomb Spectronic 70 (Bausch and Lomb, Rochester, New York) adjusted to 515 nm. The colorimeter was first adjusted to 100%T using 1 ml oxalic acid plus 9 ml distilled water. The working dye solution was read by adding 9 ml of dye solution to 1 ml oxalic acid solution in a colorimeter tube. This solution should read 30% T at 515 nm. If the reading deviated from 30% T by more than 1% T, the working dye solution was adjusted by adding either boiled distilled water or stock dye solution. After adjustment, at least 3 colorimeter readings were obtained using 1 ml oxalic acid solution plus 9 ml working dye solution. These readings provided dye blank readings for calculation of ascorbic acid content.

With the working dye solution prepared, sample analysis was undertaken. Twenty-five grams of freshly sliced carrots were blended for 3 minutes in a Waring blender with 250 ml 0.5% oxalic acid solution. After blending, the slurry was filtered through Whatman No. 2 filter paper to clarify.

One milliliter portions of this extract were pipetted into 3 matched colorimeter tubes. Nine milliliters of water were added to one tube which was used to adjust the colorimeter to read 100% T. To each of the other tubes, 9 ml of working dye solution were added using the same pipet that was used to standardize the dye. The reading on each tube was taken within 10 seconds from the beginning of the dye addition.

The ascorbic acid content was calculated using the following formula:

$$\text{Ascorbic Acid (mg/100g)} = 10.0\ (L_1 - L_2)\ \frac{\text{ml acid} + \text{g sample}}{\text{g sample}}$$

The factor 10.0 was determined as the slope of a standard curve using solutions of ascorbic acid.

L_1: the average absorbance of dye blanks (.523$\pm$ .003)
L_2: the average absorbance of sample tubes
ml acid: the volume of oxalic acid used in milliliters
g sample: the sample weight in grams

Carotenes

Samples for carotene analysis were obtained from the carrot-water slurry. Three 10 g samples of slurry were weighed into 250 ml beakers. To each beaker was added 140 ml of an Ethanol (95%) - Hexane (2:1 v/v) solution. The mixture was then stirred on a magnetic stirrer for 5 minutes at a rate to prevent layer separation.

The samples were filtered through a coarse fritted glass filter under suction. The residue left on the filter was washed with two 25 ml volumes of ethanol (95%) followed by one 25 ml volume of hexane. As much as possible, the residue remaining on the filter was not allowed to go dry during the washing procedure as the suction of air through the residue would cause oxidation of remaining carotene pigments.

The liquid was transferred to a 500 ml separatory funnel. The filter flask was rinsed with 50 ml of a 1% solution of sodium sulfate which was added to the contents

of the separatory funnel. The sodium sulfate solution was used to aid in the transfer of pigments of the hexane fraction and to reduce the possibility of emulsion formation (Association of Vitamin Chemists, Inc., 1966). The contents of the separatory funnel were gently shaken and the layers allowed to separate.

The lower water layer was drawn off into a second separatory funnel. This water fraction was then washed with three 25 ml volumes of hexane to remove any remaining pigments. Each hexane wash was added to the hexane fraction in the first separatory funnel. The water layer was then discarded.

The hexane fraction was washed with five 100 ml volumes of distilled water followed by one 50 ml volume of distilled water. The water washes were discarded. The hexane extract was then filtered through anhydrous sodium sulfate into a 250 ml volumetric flask. The separatory funnel, filter paper, and sodium sulfate were rinsed with hexane until free of pigment. The flask was made to volume with hexane. This extract represented the total carotene fraction and an aliquot of this extract was transferred to a colorimeter tube for measurement of total carotenes at 436 nm.

An additional 25 ml of the total carotene extract was removed for further purification and separation of the alpha- and beta-carotene fraction. This aliquot was evaporated by air flow to a volume of 5-10 ml in preparation for column chromatography.

Column chromatography was accomplished using a 1 + 2 mixture (weight basis) activated magnesium oxide and diatomaceous earth. The column was packed to a depth of 10-15 cm using the method described in Methods of Vitamin Assay (Association of Vitamin Chemists, Inc., 1966). The dimensions of the tube used were 22 mm o.d. x 18 cm long. Figure 2 shows an exploded diagram of the chromatographic apparatus.

The column was wetted with hexane before the extract was poured on. (Association of Vitamin Chemists, Inc., 1966). Alpha- and beta-carotenes were then eluted as a single band with acetone-hexane (1 + 9) following the procedure outlined in Official Methods of Analysis (AOAC, 1965).

The eluate was collected in a 100 ml volumetric flask and diluted to volume with hexane. The absorbance was measured at 436 nm. The carotene content was calculated as beta-carotene.

Colorimeter values were obtained using a Bausch and Lomb Spectronic 70 (Bausch and Lomb, Rochester, New York) adjusted to 436 nm.

Both total carotene and the beta-carotene eluate were caluclated as beta-carotene by comparison to a beta-carotene standard curve. Table 1 shows the values obtained in determining the beta-carotene standard curve. Pure crystalline beta-carotene was dissolved in hexane for the determinations.

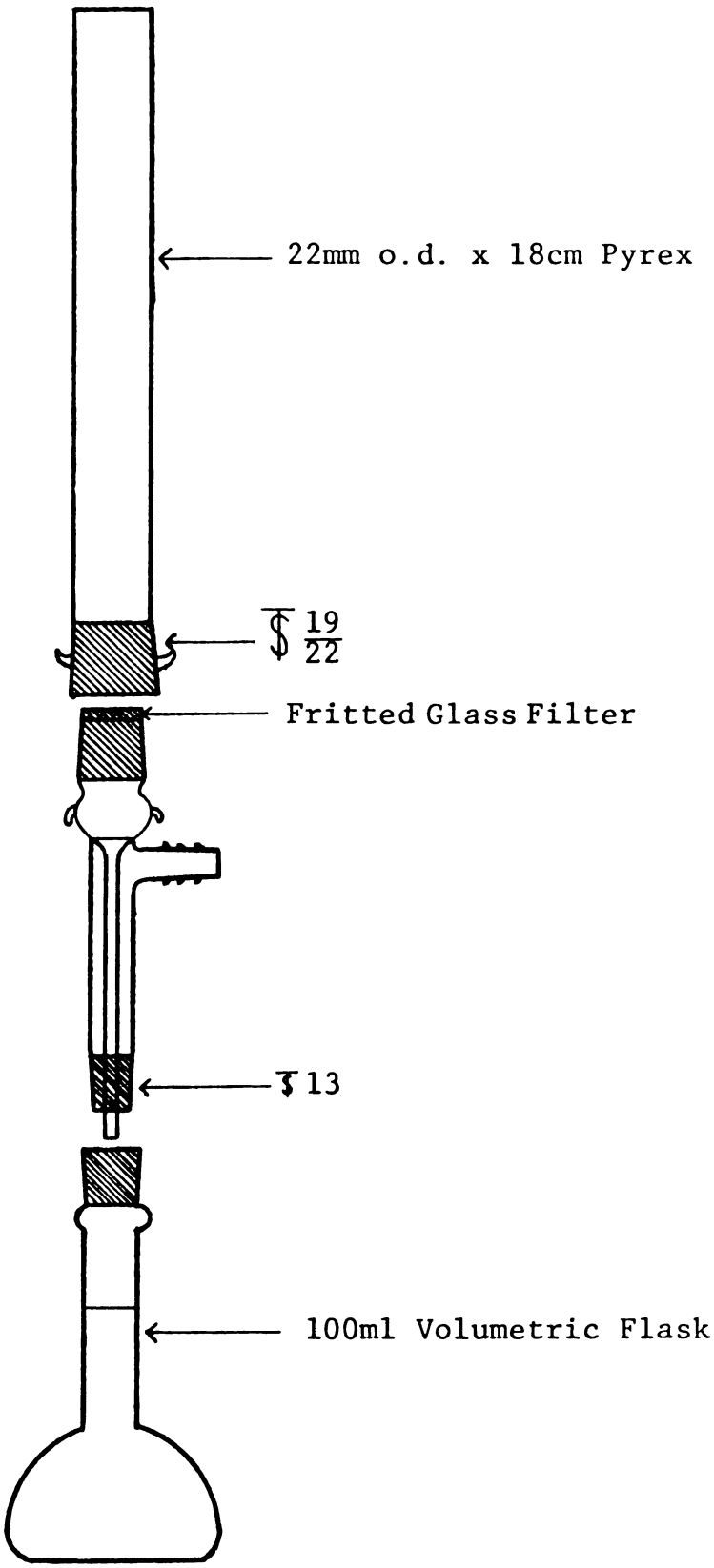

Figure 2. Column Chromatography Apparatus

Table 1. Sample Points, Beta-Carotene Standard Curve

Standard beta-carotene	SAMPLE A			SAMPLE B			
ug/ml	1	o.d.	2	1	o.d.	2	Average o.d.
0.2	.0605		.0617	.0580		.0605	.0602
0.4	.1192		.1221	.1221		.1206	.1210
0.6	.1805		.1788	.1805		.1805	.1801
0.8	.2403		.2441	.2441		.2460	.2436
1.0	.3010		.2990	.3010		.3010	.3005
1.2	.3570		.3590	.3640		.3640	.3610
1.4	.4090		.4140	.4230		.4200	.4165
1.6	.4820		.4880	.4820		.4950	.4868
1.8	.5420		.5380	.5530		.5490	.5455
2.0	.6020		.6020	.6110		.6020	.6042

Regression Equation: O.D. = 302.24 (X mg/ml) r = .999

Sugars

Reducing Sugars

Reducing sugars were determined using the Lane-Eynon General Volumetric Method outlined in the Official Methods of Analysis (AOAC, 1965).

The extract for reducing sugar determination was obtained from the carrot-water slurry. A sample of 20 g of slurry was weighed into a 100 ml volumetric flask. To this was added 19 ml of 95% ethyl alcohol, mixed, 2 ml saturated lead acetate, mixed, and 4 ml saturated disodium phosphate, mixed. The flask was then made to volume with 50% ethyl alcohol, allowed to stand 30 minutes, and filtered through Whatman No. 2 fluted

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filter paper. Reducing sugars were determined on 10 ml of the filtrate titrated with 0.5% standard dextrose solution. Results were calculated as percent reducing sugars.

Total Sugars

The same filtrate used for reducing sugar determination was used for determination of total sugars. A volume of 50 ml of the filtrate was transferred to a 100 ml volumetric flask followed by 25 ml distilled water and 10 ml concentrated HCl. The flask was allowed to stand at room temperature for at least 24 hours.

Ten milliliters of a 11.25 N NaOH solution was then used to neutralize the flask contents. The flask was made to volume with distilled water. Titration was then carried out using 10 ml of sample as with the reducing sugars procedure. Results were calculated as percent total sugars.

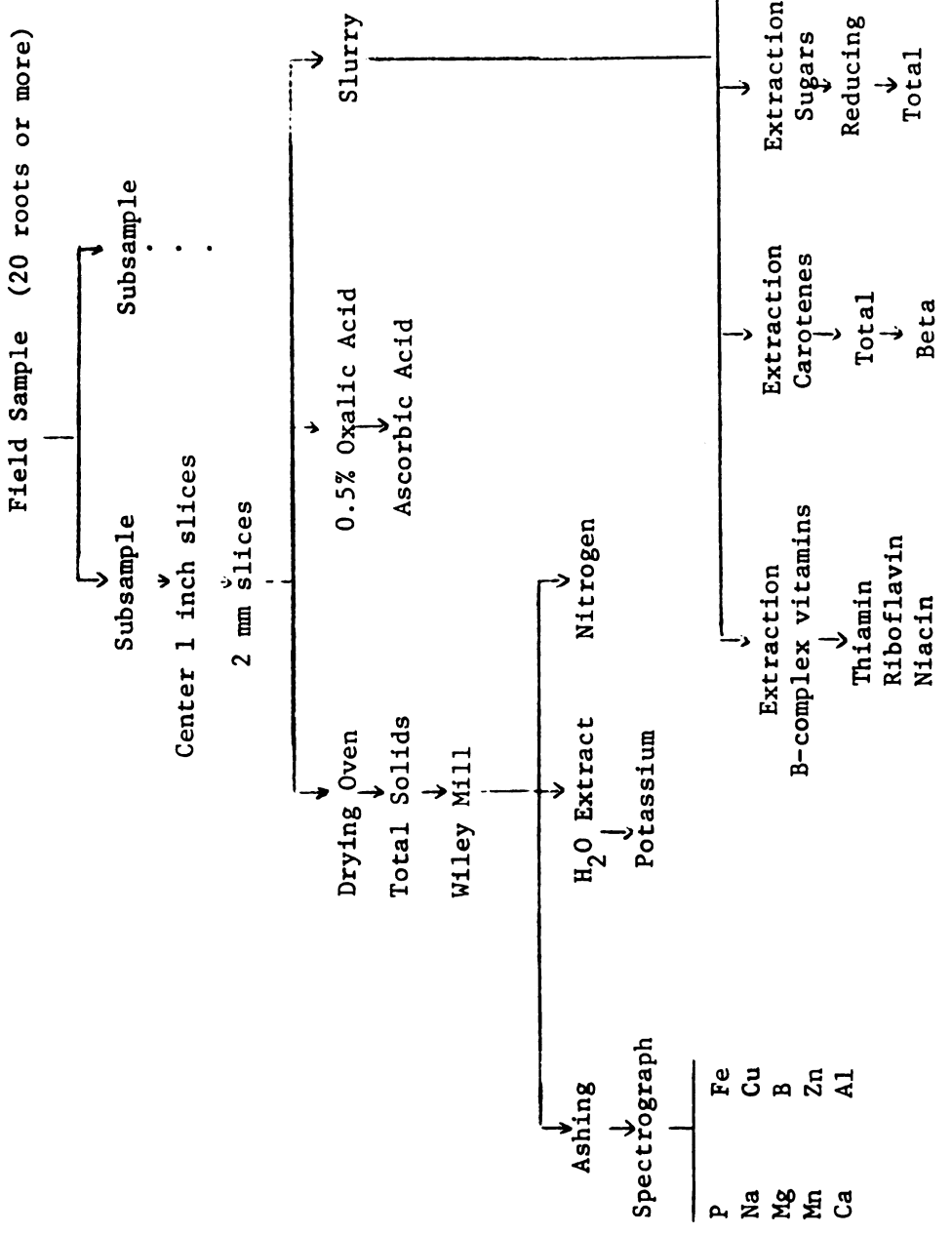

Figure 3. General Flow Diagram, Sample Handling

CANNED PRODUCT

Several of the hybrids were canned in a preliminary study to observe some reactions of the carrots to canning. Five of the carrot lines were canned in each of two growing seasons, 1971 and 1972. From the 1971 season, samples of Danvers, Spartan Bonus, Spartansweet, Spartan Fancy, and Spartan Delite lines were canned for later study. From the 1972 season, samples of Danvers, Spartan Bonus, Spartan Delux, Spartan Fancy and Spartan Delite lines were canned.

Canning Procedure

Roots to be canned were first washed in water and trimmed. The roots were then immersed in a hot 5% lye solution to loosen the peel. The peel was then removed in a cold water spray. Any peel remaining after these treatments was scraped off manually.

The roots were sliced into approximately 1/4 inch slices and spread on a perforated blanching tray. The slices were blanched in live steam for 2 minutes and filled into 303 x 406 'C' enamel cans. A net fill weight of 11 ounces was used. The slices were covered with hot 2% salt brine, exhausted in boiling water for 6-7 minutes, and sealed.

The cans were retorted at 240 F (10 lb. pressure) for 30 minutes and cooled. The cooled cans were crated and stored at 50 F until opened.

Analysis Procedures

Physical measurements on the cans included can vacuum, total weight of the contents, and drained weight. Drained weight was determined using the AOAC method (AOAC, 1965).

Chemical measurements included ascorbic acid, riboflavin, thiamin, niacin, and carotenes on both the solid and liquid fractions of the can contents. These analyses were accomplished using the same procedures as used for the fresh roots, however, sample preparation and sample size were altered for several of the analyses.

Ascorbic acid was determined on the solid fraction by blending 50 g samples with 250 ml of 0.5% oxalic acid. The sample size was thus double that used for fresh roots. Ascorbic acid of the liquid fraction was determined by combining 10 ml of can liquid with 10 ml 0.5% oxalic acid. This was then filtered to clarify and analyzed by the same procedure as used for the fresh root.

Samples for analysis of carotenes, riboflavin, thiamin, and niacin were obtained from the solid fraction in the same manner as they were obtained from the fresh roots. A slurry was created by blending 100 g solids plus 200 ml distilled water for 3 minutes. Samples for carotene analysis were obtained by weigning three 10 g samples of the slurry. Riboflavin, thiamin, and niacin were extracted from 75 g of the slurry.

The carotene level in the liquid was negligible. Riboflavin, thiamin, and niacin were determined on the liquid

by adjusting 25 g of the liquid to pH 4.5 with 0.1 N HCl and 2.5 Molar sodium acetate. This was then made to a final volume of 50 ml and stored in the dark.

Subsequent purification and analysis of this extract for riboflavin and niacin followed the same procedures as used for the fresh roots. It was found, however, that analysis for thiamin required no further purification of the liquid fraction preparation as it did for the fresh roots. Thus, the single extraction of the vitamin extract with isobutanol was not used for the liquid fraction thiamin analysis. Vitamin analysis was accomplished using the automated procedures described for the fresh roots.

Statistical Methods

Significance of laboratory findings between varieties and between locations was tested using Duncan's Multiple Range Test (Sokal and Rohlf, 1969). The significance level, whether being No Significance, 5%, or 1%, is indicated for each set of results.

Significance between the 1972 and 1973 growing seasons was tested using the Tukey Range Test, one factor (Sokal and Rohlf, 1969). The significance level is indicated for each set of results.

Variation in the data within years was tested using Least Squares Regression, Analysis of Variance (Sokal and Rohlf, 1969). This was accomplished using the CDC 3600 computer located in the Computer Laboratory of Michigan State University (Ruble, et al. 1969).

RESULTS AND DISCUSSION

It was desirable from the outset of this study to maintain consistancy in both locations of growth and in varieties grown at any given location. Ideally a complete set of carrot samples would be obtained from each growing location, and the growing locations would remain the same from year to year. As is common with agricultural experiments of this nature, such stringent controls could not be maintained due to numerous unforseen circumstances. Thus, variations occurred in both locations and varieties over the years of this study.

In an effort to clarify this presentation, the data from those locations which provided samples in only one harvest year is contained in the Appendix. These locations include Fremont, Michigan; Ohio; Florida; and the MSU Muck Farm late planting, late harvest in 1972; and Grant and Fremont, Michigan in 1973.

Various combinations of planting and harvest dates occurred which warrant definition. The term "Late Harvest," when used, indicates that the samples were given a longer growing period that other samples from the same location. The terms "Early Planting" and "Late Planting" refer to planting time as being either early in the season or later in the season. The length of the growing period for these samples is within the normal range, however the effects of environment on different growth stages has been shifted within the season.

Due to the amount of data contained in some tables, it was necessary to reduce location and variety names to a shorter form. The shortened forms used are shown in Table 2.

Fresh Market Lines

The results found for the fresh market carrot lines are contained in Tables 3-14. Means of these tables are found in Tables 32-35.

The Fresh Market carrot lines were grown at four locations: MSU Muck Farm; Imlay City, Michigan; Texas; and Idaho. The Muck Farm and Imlay City provided two additional samples which were a late planted set from the Muck Farm and a lated harvested set from Imlay City.

Proximate analysis results are shown in Tables 3, 4, and 5. Table 3 indicates the effect that time of planting had on these results. The effects of late planting vs. early planting were not consistent. In both years of the study the late planted carrots showed higher pH and nitrogen levels and lower reducing sugar levels. Total sugars, soluble solids, and total solids were affected more by season than by planting date. The results for these three analyses were higher in the late planted samples for the 1972 season and lower for the 1973 season than the earlier planted roots. The 1973 season was unusually wet at the Muck Farm which affected the results obtained.

There were generally no significant differences noted between the varieties in any of the analyses. Growing season

did produce values which proved to be significantly different in several instances. The varieties did not exhibit any trends at these locations, however. Gold Pak and Spartansweet generally showed higher values than Spartan Fancy or Spartan Delite.

Table 4 shows the effect that a longer growing period had on the proximate analyses. As expected, the results for the late harvested samples were generally higher than those of the earlier harvest. Little significance was found between the varieties at each of the locations. Growing season produced significant differences in values most notably in reducing sugars and total sugars which were both lower in the 1973 growing season.

Table 5 shows the results found for Texas and Idaho, a southern and a northern growing climate. The pH values tended to remain relatively constant between the two locations. Higher nitrogen levels were found in roots from the Texas location whereas reducing sugars, total sugars, soluble solids, and total solids were higher in samples from the Idaho location. The variety Gold Pak tended to have higher values than the Spartan varieties, however no significances were found. Differences between years were greater than differences between varieties.

As shown in Table 6, no differences were found between locations of growth for any given variety. The values did vary between locations, although not significantly, and several trends can be discerned. Carrots grown at the Muck

Table 2. Location and Variety Codes

Code	Identification
A. Fresh Market Lines	
Sweet	Spartansweet
Fancy	Spartan Fancy
Delite	Spartan Delite
Gold Pak	Gold Pak
B. Canning Lines	
Bonus	Spartan Bonus
Danvers	Danvers
C. Parent Lines	
872	MSU 872
5931	MSU 5931
6000	MSU 6000
9541	MSU 9541
5986	MSU 5986
D. Locations	
Muk Fm E	MSU Muck Farm, Early Planting
Texas	Texas
Idaho	Idaho
Im Cty	Imlay City, Michigan
Im Cty L	Imlay City, Michigan, Late Harvest
Muk Fm L	MSU Muck Farm, Late Planting

Table 3. Fresh Market Carrots, Proximate Analysis of Muck Farm, Early Planted and Muck Farm, Late Planted Samples

Variety	pH 72*	pH 73**	sig	% Nitrogen 72	% Nitrogen 73	sig	% Reducing Sugars 72	% Reducing Sugars 73	sig	% Total Sugars 72	% Total Sugars 73	sig	% Soluble Solids 72	% Soluble Solids 73	sig	% Total Solids 72	% Total Solids 73	sig
A. Muck Farm, Early Planting																		
Gold Pak	5.99	5.93	NS	1.87	1.96	NS	2.45	2.90	1%	3.30	6.19	1%	5.88	9.00	1%	8.99	14.11	1%
Fancy	—	5.69	—	—	1.59	—	—	4.04	—	—	5.85	—	—	9.00	—	—	13.71	—
Delite	—	5.81	—	—	1.44	—	—	3.73	—	—	6.30	—	—	9.17	—	—	13.99	—
Sweet	5.88	5.72	1%	1.69	1.34	5%	2.79	4.16	1%	4.91	6.07	1%	6.95	8.40	1%	10.07	14.30	1%
sig	NS	NS		NS	5%		NS	NS		NS	NS		NS	NS		NS	NS	
B. Muck Farm, Late Planting																		
Gold Pak	6.18	6.06	NS	2.03	2.34	NS	2.49	0.56	1%	5.67	4.91	5%	9.80	6.60	1%	13.44	12.76	NS
Fancy	6.19	6.05	NS	1.94	1.81	NS	2.60	0.51	1%	5.50	5.92	NS	9.25	6.75	1%	12.52	12.11	NS
Delite	6.21	6.01	NS	1.75	1.62	NS	2.73	0.10	1%	6.25	5.62	NS	9.55	6.60	1%	13.55	12.15	NS
Sweet	6.06	6.00	NS	1.90	1.79	NS	2.49	0.71	1%	6.01	5.51	NS	9.92	6.90	1%	13.56	11.82	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance
* = growing season 1972
** = growing season 1973

Table 4. Fresh Market Carrots, Proximate Analysis of Imlay City and Imlay City, Late Harvested Samples

Variety	pH 72*	pH 73**	sig	% Nitrogen 72	% Nitrogen 73	sig	% Reducing Sugars 72	% Reducing Sugars 73	sig	% Total Sugars 72	% Total Sugars 73	sig	% Soluble Solids 72	% Soluble Solids 73	sig	% Total Solids 72	% Total Solids 73	sig
A. Imlay City, Normal Harvest																		
Delite	5.96	5.90	NS	1.46	1.38	NS	0.88	0.41	1%	5.59	5.74	NS	8.60	7.95	NS	11.79	11.52	NS
Sweet	5.98	5.75	5%	1.54	1.70	NS	1.69	0.47	1%	6.07	5.55	1%	9.12	7.05	NS	11.92	11.58	NS
Fancy	6.00	--	--	1.48	--	--	1.21	--	--	4.95	--	--	7.60	--	--	11.71	---	--
Gold Pak	6.01	5.98	NS	1.52	1.53	NS	2.47	0.85	1%	4.90	5.21	NS	7.55	8.40	NS	10.75	12.47	5%
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. Imlay City, Late Harvest																		
Delite	6.15	5.78	NS	1.29	1.45	NS	1.57	0.49	1%	6.34	4.16	1%	8.70	8.48	NS	12.48	12.57	NS
Sweet	6.16	5.80	1%	1.36	1.68	NS	1.68	0.63	1%	6.22	4.39	1%	9.45	8.90	NS	12.91	11.95	NS
Fancy	6.15	5.85	5%	1.35	1.46	NS	1.65	0.54	1%	5.65	5.55	NS	9.78	8.93	NS	13.22	13.49	NS
Gold Pak	6.04	5.90	NS	1.43	1.88	NS	2.18	0.73	1%	5.40	4.80	5%	8.37	9.08	NS	12.04	11.91	NS
sig	NS	NS		NS	NS		NS	NS		5%	NS		NS	NS		NS	NS	

NS = No Significance
* = growing season 1972
** = growing season 1973

Table 5. Fresh Market Carrots, Proximate Analysis of Texas and Idaho Samples

Variety	pH 72*	pH 73**	sig	% Nitrogen 72	% Nitrogen 73	sig	% Reducing Sugars 72	% Reducing Sugars 73	sig	% Total Sugars 72	% Total Sugars 73	sig	% Soluble Solids 72	% Soluble Solids 73	sig	% Total Solids 72	% Total Solids 73	sig
A. Texas																		
Sweet	6.47	6.15	1%	1.16	0.91	NS	1.51	1.42	NS	6.75	6.11	1%	8.60	7.50	1%	12.60	11.41	5%
Fancy	6.53	6.11	1%	1.19	1.03	NS	1.41	1.70	NS	6.45	6.07	NS	8.30	8.03	NS	12.93	11.61	NS
Delite	6.38	6.20	1%	1.22	0.93	5%	1.08	1.25	NS	6.19	6.15	NS	8.25	9.00	1%	12.52	11.77	NS
Gold Pak	—	6.07	—	—	1.13	—	—	1.80	—	—	5.85	—	—	9.00	—	—	11.43	—
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. Idaho																		
Sweet	6.25	6.20	NS	0.75	0.84	NS	2.70	1.73	1%	7.65	7.35	NS	10.05	9.00	5%	13.25	12.33	5%
Fancy	6.29	6.20	NS	0.88	0.90	NS	2.61	1.80	1%	7.65	7.20	5%	9.20	9.00	NS	13.13	12.43	5%
Delite	6.32	6.20	5%	1.01	0.98	NS	2.32	1.46	1%	6.75	6.75	NS	9.00	9.00	NS	13.00	12.80	NS
Gold Pak	—	6.25	—	—	1.16	—	—	2.02	—	—	6.90	—	—	9.60	—	—	13.07	—
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance
* = growing season 1972
** = growing season 1973

Table 6. Fresh Market Carrots, Proximate Analysis by Variety at Six Locations

Location	pH 72*	pH 73**	sig	% Nitrogen 72	% Nitrogen 73	sig	% Reducing Sugars 72	% Reducing Sugars 73	sig	% Total Sugars 72	% Total Sugars 73	sig	% Soluble Solids 72	% Soluble Solids 73	sig	% Total Solids 72	% Total Solids 73	sig
A. Spartansweet																		
Muk Fm E	5.88	5.72	1%	1.69	1.34	5%	2.79	4.16	1%	4.91	6.07	1%	6.95	8.40	1%	10.07	14.32	1%
Texas	6.47	6.15	1%	1.16	0.91	NS	1.51	1.42	NS	6.75	6.11	1%	8.60	7.50	1%	12.60	11.41	5%
Idaho	6.25	6.20	NS	0.75	0.84	NS	2.70	1.73	1%	7.65	7.35	NS	10.05	9.00	5%	13.25	12.33	5%
Im Cty	5.98	5.75	5%	1.54	1.70	NS	1.69	0.47	1%	6.07	5.55	1%	9.12	7.05	1%	11.92	11.58	NS
Im Cty L	6.16	5.80	1%	1.36	1.68	NS	1.69	0.63	1%	6.22	4.39	1%	9.45	8.90	NS	12.91	11.95	NS
Muk Fm L	6.06	6.00	NS	1.90	1.79	NS	2.49	0.71	1%	6.01	5.51	NS	9.92	6.90	1%	13.56	11.82	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. Spartan Fancy																		
Muk Fm E	—	5.69	—	—	1.59	—	—	4.04	—	—	5.85	—	—	9.00	—	—	13.71	—
Texas	6.53	6.11	1%	1.19	1.03	NS	1.61	1.70	NS	6.45	6.07	NS	8.30	8.03	NS	12.93	11.61	NS
Idaho	6.29	6.20	1%	0.88	0.90	NS	2.61	1.80	1%	7.65	7.20	5%	9.20	9.00	NS	13.13	12.43	5%
Im Cty	6.00	—	—	1.48	—	—	1.21	—	—	4.95	—	—	7.60	—	—	11.71	—	—
Im Cty L	6.15	5.85	5%	1.35	1.46	NS	1.65	0.54	1%	5.65	5.55	NS	9.78	8.93	NS	13.22	13.49	NS
Muk Fm L	6.19	6.05	NS	1.94	1.81	NS	2.60	0.51	1%	5.50	5.92	NS	9.25	6.75	1%	12.52	12.11	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
C. Spartan Delite																		
Muk Fm E	—	5.81	—	—	1.44	—	—	3.73	—	—	6.30	—	—	9.17	—	—	13.99	—
Texas	6.38	6.20	1%	1.22	0.93	5%	1.08	1.25	NS	6.19	6.15	NS	8.25	9.00	1%	12.52	11.77	NS
Idaho	6.32	6.20	5%	1.01	0.98	NS	2.32	1.46	1%	6.75	6.75	NS	9.00	9.00	NS	13.00	12.80	NS
Im Cty	5.96	5.90	NS	1.46	1.38	NS	0.88	0.41	1%	5.59	5.74	NS	8.60	7.95	NS	11.79	11.52	NS
Im Cty L	6.15	5.78	NS	1.29	1.45	NS	1.57	0.49	1%	6.34	4.16	1%	8.70	8.48	1%	12.48	12.57	NS
Muk Fm L	6.21	6.01	NS	1.75	1.62	NS	2.73	0.10	1%	6.25	5.62	NS	9.55	6.60	1%	13.55	12.15	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
D. Gold Pak																		
Muk Fm E	5.99	5.93	NS	1.87	1.96	NS	2.45	2.90	1%	3.30	6.19	1%	5.88	9.00	1%	8.99	14.11	1%
Texas	—	6.07	—	—	1.13	—	—	1.80	—	—	5.85	—	—	9.00	—	—	11.43	—
Idaho	—	6.25	—	—	1.16	—	—	2.02	—	—	6.90	—	—	9.60	—	—	13.07	—
Im Cty	6.01	5.98	NS	1.53	1.53	NS	2.47	0.85	1%	4.90	5.21	NS	7.55	8.40	NS	10.75	12.47	5%
Im Cty L	6.04	5.90	NS	1.43	1.88	NS	2.18	0.73	1%	5.40	4.80	5%	8.37	9.08	NS	12.04	11.91	NS
Muk Fm L	6.18	6.06	NS	2.03	2.35	NS	2.49	0.56	1%	5.67	4.91	5%	9.80	6.60	1%	13.44	12.76	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance
* = growing season 1972
** = growing season 1973

Farm tended to have higher total solids than those grown at other locations although the trend was not consistent for either the early or late planted samples. The early planted carrots at the Muck Farm had a consistently lower pH than the other locations. The late planted carrots at the Muck Farm had a consistently higher nitrogen level. The Idaho samples were consistently high in total sugars and also ranked high in reducing sugars and soluble solids.

A comparison of the instances of significance, by count, between growing seasons seems to indicate that Spartansweet is very sensitive to environmental changes. Missing data caused this to be a rough determination, but including as significant missing comparisons within the other varieties, Spartansweet maintains greater differences between seasons. The remaining varieties appear to be relatively equal in stability to environmental changes.

Vitamin assay of the Muck Farm, early and late planted samples (Table 7) showed greater differences between years than among varieties. No significance was found between varieties. Thiamin, niacin, ascorbic acid, total carotenes, and beta carotene showed significant differences between years. At both locations the 1972 season produced higher riboflavin and niacin levels and lower thiamin, total, and beta carotene levels than the 1973 season. Early planting produced higher ascorbic acid in the 1973 season and late planting produced higher ascorbic acid in the 1972 season.

Since carotene is the vitamin component readily associated with carrot roots, it is of interest to note

that the variety Gold Pak produced the highest carotene levels at the Muck Farm.

Table 8 shows the vitamin assay results obtained from the Imlay City samples. No significance was shown among varieties while several significant differences were found between growing seasons. As was true with the Muck Farm samples (Table 7) higher riboflavin and niacin levels were reached in the 1972 growing season. Thiamin levels were lower in the 1972 season which was also true of the Muck Farm samples. Carotenes were generally higher in 1972 than in 1973 which was the reverse of the Muck Farm samples. In the normally harvested samples Spartansweet produced the highest carotene levels in 1972 and Gold Pak produced the highest carotene levels in 1973. Spartan Fancy produced the highest carotene levels of the late harvested samples. Ascorbic acid levels were higher in 1973 for both sets of samples.

Texas and Idaho samples (Table 9) were higher in vitamin levels in the 1972 growing season than in the 1973 growing season. No significance was found between varieties while some differences occurred between years. Carotene levels were relatively constant for all varieties at these two locations.

Comparisons among all locations for each variety showed that roots from the locations did not differ significantly in vitamin production (Table 10). The Muck Farm samples tended to be higher in riboflavin and thiamin than the other locations. Carotene levels also tended to be higher in the

Table 7. Fresh Market Carrots, Vitamin Assay of Muck Farm, Early Planted and Muck Farm, Late Planted Samples

Variety	Riboflavin ug/g 72*	Riboflavin ug/g 73**	sig	Thimain ug/g 72	Thimain ug/g 73	sig	Niacin ug/g 72	Niacin ug/g 73	sig	Ascorbic Acid mg/100g 72	Ascorbic Acid mg/100g 73	sig	Carotene mg/g Total 72	Carotene mg/g Total 73	sig	Carotene mg/g Beta 72	Carotene mg/g Beta 73	sig
A. Muck Farm, Early Planting																		
Sweet	0.73	0.72	NS	0.86	1.23	5%	5.94	3.38	1%	4.65	13.00	1%	0.13	0.19	1%	0.12	0.17	1%
Fancy	--	0.79	--	--	1.35	--	--	3.04	--	--	14.34	--	--	0.19	--	--	0.17	--
Delite	--	0.76	--	--	1.31	--	--	3.06	--	--	13.58	--	--	0.19	--	--	0.17	--
Gold Pak	0.60	0.97	NS	0.54	1.32	1%	7.28	3.41	1%	7.12	13.97	1%	0.13	0.25	1%	0.12	0.22	1%
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. Muck Farm, Late Planting																		
Sweet	1.04	0.73	NS	1.35	1.46	NS	8.16	2.59	1%	8.48	5.84	5%	0.22	0.20	NS	0.21	0.19	NS
Fancy	0.78	0.72	NS	1.49	1.93	5%	6.54	3.33	1%	8.91	6.29	NS	0.21	0.26	5%	0.20	0.24	5%
Delite	0.88	0.76	NS	1.37	1.66	NS	8.81	2.24	1%	9.56	8.54	NS	0.22	0.25	NS	0.20	0.23	NS
Gold Pak	0.97	0.76	NS	1.26	1.70	5%	7.69	3.01	1%	8.15	6.95	NS	0.25	0.28	NS	0.24	0.26	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance
* = growing season 1972
** = growing season 1973

Table 8. Fresh Market Carrots, Vitamin Assay of Imlay City, and Imlay City, Late Harvested Samples

Variety	Riboflavin ug/g 72*	Riboflavin ug/g 73**	sig	Thiamin ug/g 72	Thiamin ug/g 73	sig	Niacin ug/g 72	Niacin ug/g 73	sig	Ascorbic Acid mg/100g 72	Ascorbic Acid mg/100g 73	sig	Carotenes, mg/g Total 72	Carotenes, mg/g Total 73	sig	Carotenes, mg/g Beta 72	Carotenes, mg/g Beta 73	sig
A. Imlay City, Normal Harvest																		
Sweet	0.84	0.70	5%	0.84	1.23	NS	9.19	2.48	1%	6.26	11.15	1%	0.21	0.18	1%	0.20	0.16	1%
Fancy	0.48	—	--	1.00	--	--	4.94	--	--	5.07	---	--	0.18	--	—	0.17	--	--
Delite	0.73	0.69	NS	0.42	1.09	1%	9.36	2.69	1%	5.91	13.36	1%	0.19	0.17	NS	0.18	0.15	NS
Gold Pak	0.69	0.69	NS	0.69	1.04	NS	7.34	3.46	5%	6.19	15.35	1%	0.18	0.19	NS	0.17	0.17	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. Imlay City, Late Harvest																		
Sweet	0.66	0.57	NS	0.68	1.02	NS	4.44	2.52	NS	6.36	8.18	NS	0.21	0.19	5%	0.21	0.18	5%
Fancy	0.92	0.73	NS	0.88	1.08	NS	7.80	2.78	5%	7.70	10.96	1%	0.23	0.22	NS	0.22	0.21	NS
Delite	0.70	0.77	NS	0.82	1.02	NS	8.30	2.32	1%	6.46	11.53	1%	0.21	0.22	NS	0.19	0.20	NS
Gold Pak	0.79	0.72	NS	0.54	0.98	NS	6.16	3.94	NS	6.35	8.94	1%	0.23	0.22	NS	0.21	0.20	NS
sig	,NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance
* = growing season 1972
** = growing season 1973

Table 9. Fresh Market Carrots, Vitamin Assay of Texas and Idaho Samples

Variety	Riboflavin ug/g 72*	Riboflavin ug/g 73**	sig	Thiamin ug/g 72	Thiamin ug/g 73	sig	Niacin ug/g 72	Niacin ug/g 73	sig	Ascorbic Acid mg/100g 72	Ascorbic Acid mg/100g 73	sig	Carotenes, mg/g Total 72	Carotenes, mg/g Total 73	sig	Carotenes, mg/g Beta 72	Carotenes, mg/g Beta 73	sig
A. Texas																		
Sweet	0.60	0.47	NS	0.83	0.81	NS	3.12	1.44	5%	9.03	7.63	NS	0.16	0.16	NS	0.15	0.15	NS
Fancy	0.68	0.47	NS	0.93	0.81	NS	3.67	1.82	5%	11.66	8.12	1%	0.18	0.15	NS	0.18	0.14	5%
Delite	0.55	0.53	NS	1.04	0.79	NS	3.64	1.70	5%	9.32	11.33	1%	0.18	0.16	NS	0.16	0.15	NS
Gold Pak	--	0.49	--	--	0.81	--	--	2.46	--	---	11.06	--	--	0.14	--	--	0.12	--
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. Idaho																		
Sweet	0.43	0.61	NS	0.85	0.73	NS	5.40	0.97	1%	10.37	6.41	5%	0.18	0.15	5%	0.17	0.13	1%
Fancy	0.87	0.42	NS	0.85	1.27	1%	6.01	1.46	1%	12.42	9.09	5%	0.19	0.17	NS	0.19	0.15	1%
Delite	0.83	0.60	NS	0.73	0.75	NS	5.49	1.21	1%	11.71	9.55	1%	0.18	0.15	5%	0.17	0.14	5%
Gold Pak	--	0.36	--	--	0.85	--	--	2.48	--	---	10.88	--	--	0.14	--	--	0.13	--
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance
* = growing season 1972
** = growing season 1973

Table 10. Fresh Market Carrots, Vitamin Assay by Variety at Six Locations

	Riboflavin ug/g			Thiamin ug/g			Niacin ug/g			Ascorbic Acid mg/100g			Carotenes, mg/g Total			Carotenes, mg/g Beta		
	72*	72**	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig
A. Spartansweet																		
Muk Fm E	0.73	0.72	NS	0.86	1.23	5%	5.94	3.38	1%	4.65	13.0	1%	0.13	0.19	1%	0.12	0.17	1%
Texas	0.60	0.47	NS	0.83	0.81	NS	3.12	1.44	5%	9.03	9.03	NS	0.16	0.16	NS	0.15	0.15	NS
Idaho	0.43	0.61	NS	0.85	0.73	NS	5.40	0.97	1%	10.37	6.41	5%	0.18	0.15	5%	0.17	0.13	1%
Im Cty	0.84	0.70	5%	0.84	1.23	NS	9.19	2.48	1%	6.26	11.15	1%	0.21	0.18	1%	0.20	0.16	1%
Im Cty L	0.66	0.57	NS	0.68	1.02	NS	4.44	2.52	NS	6.36	8.18	NS	0.21	0.19	5%	0.21	0.18	5%
Muk Fm L	1.04	0.73	NS	1.35	1.46	NS	8.16	2.59	1%	8.48	5.84	5%	0.22	0.20	NS	0.21	0.19	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. Spartan Fancy																		
Muk Fm E	--	0.79	--	--	1.35	--	--	3.04	--	--	14.34	--	--	0.19	--	--	0.17	--
Texas	0.68	0.47	NS	0.93	0.81	NS	3.67	1.82	5%	11.66	8.12	1%	0.18	0.15	NS	0.18	0.14	5%
Idaho	0.87	0.42	NS	0.85	1.27	1%	6.01	1.46	1%	12.42	9.09	5%	0.19	0.17	NS	0.19	0.15	1%
Im Cty	0.48	--	--	1.00	--	--	4.94	--	--	5.07	--	--	0.18	--	--	0.17	--	--
Im Cty L	0.92	0.73	NS	0.88	1.08	NS	7.80	2.78	5%	7.70	10.96	1%	0.23	0.22	NS	0.22	0.21	NS
Muk Fm L	0.78	0.72	NS	1.49	1.93	5%	6.54	3.33	1%	8.91	6.29	NS	0.21	0.26	5%	0.20	0.24	5%
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
C. Spartan Delite																		
Muk Fm E	--	0.76	--	--	1.31	--	--	3.06	--	--	13.58	--	--	0.19	--	--	0.17	--
Texas	0.55	0.53	NS	1.04	0.79	NS	3.64	1.70	5%	8.32	11.33	1%	0.18	0.16	NS	0.16	0.15	NS
Idaho	0.83	0.60	NS	0.73	0.75	NS	5.49	1.31	1%	11.71	9.55	1%	0.18	0.15	5%	0.17	0.14	5%
Im Cty	0.73	0.69	NS	0.42	1.09	1%	9.36	2.69	1%	5.91	13.36	1%	0.19	0.17	NS	0.18	0.15	NS
Im Cty L	0.70	0.77	NS	0.82	1.02	NS	8.30	2.32	1%	6.46	11.53	1%	0.21	0.22	NS	0.19	0.20	NS
Muk Fm L	0.88	0.76	NS	1.37	1.66	NS	8.81	2.24	1%	9.56	8.54	NS	0.22	0.25	NS	0.20	0.23	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
D. Gold Pak																		
Muk Fm E	0.60	0.97	NS	0.54	1.32	1%	7.38	3.41	1%	7.12	13.97	1%	0.13	0.25	1%	0.12	0.22	1%
Texas	--	0.49	--	--	0.81	--	--	2.46	--	--	11.06	--	--	0.14	--	--	0.12	--
Idaho	--	0.36	--	--	0.85	--	--	2.48	--	--	10.88	--	--	0.14	--	--	0.13	--
Im Cty	0.69	0.69	NS	0.69	1.04	NS	7.34	3.46	5%	6.19	15.35	1%	0.18	0.19	NS	0.16	0.17	NS
Im Cty L	0.79	0.72	NS	0.54	0.98	NS	6.16	3.94	NS	6.35	8.94	1%	0.23	0.22	NS	0.21	0.20	NS
Muk Fm L	0.97	0.76	NS	1.26	1.70	5%	7.69	3.01	1%	8.15	6.95	NS	0.25	0.28	NS	0.24	0.26	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance
* = growing season 1972
** = growing season 1973

Muck Farm samples with a tendency for the late planted roots to have higher levels. Spartansweet again showed sensitivity to seasonal changes.

Mineral levels of the fresh market varieties are recorded in Tables 11, 12, 13, and 14. Table 11 shows the Muck Farm, Early Planting and Muck Farm, Late Planting mineral content. Significance was shown between varieties Gold Pak and Spartan Fancy in the Muck Farm, Early Planted samples for iron and copper content. There were no significant differences in the other minerals. Some differences occurred between years.

Table 12 contains the results from Imlay City and Imlay City, Late Harvest. The late harvested samples showed significant differences between Gold Pak and Spartan Fancy for magnesium in both years of the study. Gold Pak and Spartan Delite were significantly different for copper in the 1973 season. Greater differences occurred between years than among varieties.

The results from the Texas and Idaho samples are shown in Table 13. Significance was shown between Spartan Fancy and Gold Pak for sodium in the 1973 season at the Texas location. No other significances were found between varieties. Several instances of seasonal differences were noted.

Although Gold Pak and Spartan Fancy varieties showed some significant differences at several of the locations for several of the minerals, they did not consistently command the high and low values within a data set. It appears that the

mineral levels attained are dependent on numerous interactions of the root with its environment since the levels vary greatly between locations and years.

Location did not affect mineral levels, as shown in Table 14. The only trends observed were potassium levels, which were higher in the 1972 season, and copper levels, which were higher in the 1973 season. Spartansweet variety showed a greater sensitivity to seasonal changes than did the other varieties.

It appears that the fresh market varieties are essentially the same in composition. No consistent statistical differences were found among the varieties or the locations of growth. No one variety stood out as being superior to the others in any category. Spartansweet did show a tendency to be more sensitive to environmental changes as judged by the number of statistical differences between growing seasons.

Canning Lines

The results found for the canning carrot varieties are contained in Tables 15-20. These tables are summarized as mean values in Tables 32-35.

Samples of the canning varieties were obtained from the Muck Farm, Early Planting, Texas, Idaho, and the Muck Farm, Late Planting.

The proximate analysis results for each location are contained in Table 15. No significant differences were found between the two varieties. Some differences between growing

Table 11. Fresh Market Carrots, Mineral Levels of Muck Farm, Early Planted and Muck Farm, Late Planted Samples

Variety yr:	%K 72	%K 73	sig	%P 72	%P 73	sig	Na mg/100g 72	Na mg/100g 73	sig	%Ca 72	%Ca 73	sig	%Mg 72	%Mg 73	sig	Mn mg/100g 72	Mn mg/100g 73	sig	Fe mg/100g 72	Fe mg/100g 73	sig	Cu mg/100g 72	Cu mg/100g 73	sig	B mg/100g 72	B mg/100g 73	sig	Zn mg/100g 72	Zn mg/100g 73	sig	Al mg/100g 72	Al mg/100g 73	sig
A. Muck Farm, Early Planting																																	
Gold Pak	3.67	2.92	NS	0.57	0.57	NS	236	146	5%	0.27	0.27	NS	0.16	0.14	5%	0.10	1.25	5%	1.80	9.60	NS	0.08	1.36	NS	2.51	2.20	NS	0.35	2.85	5%	4.75	14.30	NS
Sweet	3.40	2.82	1%	0.59	0.50	5%	314	129	1%	0.19	0.24	NS	0.12	0.12	NS	0.10	1.90	5%	1.80	5.80	1%	0.04	0.87	NS	2.11	2.29	NS	0.40	2.60	5%	3.80	12.15	1%
Delite	--	3.10	--	--	0.48	--	---	151	--	--	0.18	--	--	0.12	--	--	0.65	--	--	5.35	--	--	0.71	--	--	2.06	--	--	1.70	--	--	20.25	--
Fancy	--	3.05	--	--	0.51	--	---	137	--	--	0.19	--	--	0.13	--	--	0.40	--	--	4.60	--	--	0.59	--	--	2.01	--	--	1.40	--	--	6.85	--
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	5%		NS	5%		NS	NS		NS	NS		NS	NS	
B. Muck Farm, Late Planting																																	
Gold Pak	3.81	2.65	5%	0.48	0.55	NS	136	181	NS	0.38	0.36	NS	0.17	0.17	NS	0.10	0.95	5%	1.87	4.60	1%	0.17	1.28	5%	2.26	2.47	NS	1.60	2.70	NS	4.90	0.10	NS
Sweet	3.58	2.26	NS	0.53	0.45	NS	227	387	NS	0.40	0.29	NS	0.13	0.11	NS	0.15	0.20	NS	4.67	3.55	NS	0.56	0.79	NS	2.13	2.11	NS	1.30	14.95	NS	6.65	0.10	NS
Delite	3.52	2.70	NS	0.49	0.39	NS	175	203	NS	0.38	0.25	NS	0.12	0.11	NS	0.15	0.10	NS	1.80	3.05	NS	0.31	0.71	NS	2.09	2.15	NS	1.20	0.85	NS	4.72	0.10	NS
Fancy	3.83	2.47	NS	0.54	0.51	NS	208	254	NS	0.34	0.29	NS	0.13	0.12	NS	0.10	0.30	NS	1.57	3.05	5%	0.01	0.84	1%	1.99	2.38	NS	1.22	1.55	NS	6.17	0.10	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

Table 12. Fresh Market Carrots, Mineral Level of Imlay City, and Imlay City Late Harvested Samples

Variety	yr:	%K 72	%K 73	sig	%P 72	%P 73	sig	Na mg/100g 72	Na mg/100g 73	sig	%Ca 72	%Ca 73	sig	%Mg 72	%Mg 73	sig	Mn mg/100g 72	Mn mg/100g 73	sig	Fe mg/100g 72	Fe mg/100g 73	sig	Cu mg/100g 72	Cu mg/100g 73	sig	B mg/100g 72	B mg/100g 73	sig	Zn mg/100g 72	Zn mg/100g 73	sig	Al mg/100g 72	Al mg/100g 73	sig
A. Imlay City																																	
Gold Pak		3.67	2.91	5%	0.36	0.51	5%	172	243	NS	0.19	0.12	NS	0.11	0.12	NS	0.01	1.10	1%	1.65	5.20	5%	0.33	0.55	NS	2.04	2.20	NS	0	2.20	1%	23.35	7.95	NS
Delite		3.35	2.48	5%	0.40	0.44	NS	227	513	NS	0.18	0.20	NS	0.1	0.12	NS	0.01	1.60	1%	1.35	6.80	5%	0.82	0.84	NS	1.98	2.75	1%	2.70	2.70	NS	3.15	22.95	NS
Sweet		3.40	3.25	NS	0.42	0.47	NS	275	182	1%	0.02	0.13	NS	0.10	0.15	1%	0.01	1.05	NS	1.50	6.20	5%	0.47	0.75	NS	1.84	2.56	NS	0	2.25	5%	24.00	10.85	NS
Fancy		3.51	--	--	0.41	--	--	244	---	--	0.20	--	--	0.14	--	--	0.35	--	--	2.65	--	--	0.85	--	--	2.01	--	--	0.60	--	--	12.65	---	--
	sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. Imlay City, Late Harvest																																	
Gold Pak		3.77	2.78	NS	0.43	0.48	NS	204	182	NS	0.39	0.26	5%	0.15	0.14	NS	0.60	2.75	NS	2.67	5.50	NS	1.25	0.96	NS	2.49	2.70	NS	1.30	1.85	NS	20.50	3.40	NS
Delite		3.16	2.74	NS	0.40	0.44	NS	216	258	NS	0.41	0.10	1%	0.13	0.11	NS	0.75	0.80	NS	2.25	4.45	5%	0.47	0.55	NS	2.07	2.29	NS	0.95	0.65	NS	8.80	6.85	NS
Sweet		3.72	2.87	1%	0.46	0.49	NS	226	286	NS	0.33	0.15	NS	0.12	0.13	NS	0.60	1.90	NS	2.40	4.00	NS	0.58	0.30	5%	2.11	2.29	NS	0.70	0.40	NS	9.15	1.00	5%
Fancy		3.30	2.39	NS	0.42	0.46	5%	237	235	NS	0.29	0.14	5%	0.11	0.10	NS	0.10	1.25	5%	1.80	2.75	5%	0.51	0.17	1%	2.31	2.10	NS	1.25	0.40	NS	10.75	1.55	5%
	sig	NS	NS		NS	NS		NS	NS		NS	NS		5%	5%		NS	NS		NS	NS		NS	5%		NS	NS		NS	NS		NS	NS	

Table 13. Fresh Market Carrots, Mineral Levels of Texas and Idaho Supplies

Variety yr:	%K 72	%K 73	sig	%P 72	%P 73	sig	Na mg/100g 72	Na mg/100g 73	sig	%Ca 72	%Ca 73	sig	%Mg 72	%Mg 73	sig	Mn mg/100g 72	Mn mg/100g 73	sig	Fe mg/100g 72	Fe mg/100g 73	sig	Cu mg/100g 72	Cu mg/100g 73	sig	B mg/100g 72	B mg/100g 73	sig	Zn mg/100g 72	Zn mg/100g 73	sig	Al mg/100g 72	Al mg/100g 73	sig
A. Texas																																	
Fancy	1.48	2.15	NS	0.27	0.39	NS	146	284	NS	0.32	0.19	NS	0.11	0.09	1%	0.10	0.10	NS	2.25	4.75	NS	0.04	0.83	NS	1.84	1.83	NS	0.15	0.30	NS	12.30	14.70	NS
Sweet	2.74	2.18	5%	0.39	0.34	NS	237	262	NS	0.31	0.22	NS	0.12	0.09	5%	0.20	0.30	NS	2.80	4.15	NS	0.01	0.71	5%	1.84	1.78	NS	0	0.50	5%	14.55	8.20	NS
Delite	3.15	2.22	5%	0.26	0.34	1%	171	242	NS	0.29	0.20	NS	0.12	0.09	NS	0.50	0.30	NS	2.90	5.65	5%	0.01	0.71	NS	1.97	2.06	NS	0.40	0.30	NS	14.80	12.70	NS
Gold Pak	—	2.08	—	—	0.33	—	—	139	—	—	0.22	--	--	0.13	—	--	0.45	--	--	4.60	—	—	0.55	—	--	2.33	—	--	0.45	—	—	2.90	—
sig	NS	NS		NS	NS		NS	5%		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. Idaho																																	
Fancy	1.62	1.80	NS	0.16	0.26	1%	129	155	NS	0.27	0.14	NS	0.08	0.07	NS	0.10	0.10	NS	2.35	3.20	NS	0.01	0.42	1%	1.84	1.46	NS	0.20	0	NS	12.60	5.30	NS
Sweet	2.18	2.00	5%	0.22	0.27	5%	244	152	1%	0.27	0.17	1%	0.08	0.08	NS	0.10	0.10	NS	1.65	2.90	1%	0.01	0.26	1%	1.84	1.65	1%	0	0.20	1%	6.00	4.20	5%
Delite	1.90	2.00	NS	0.15	0.30	1%	131	152	5%	0.21	0.17	NS	0.09	0.08	1%	0.10	0.30	1%	2.65	3.70	5%	0.01	0.34	1%	1.84	1.65	1%	0	0.40	1%	8.55	0.10	1%
Gold Pak	—	1.68	—	—	0.28	—	—	111	--	--	0.19	--	--	0.10	—	--	0.10	—	--	4.00	—	--	0.26	—	--	1.83	--	--	0.40	—	—	0.50	--
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance

Table 14. Fresh Market Carrots, Mineral Levels by Variety at Six Locations

Location yr:	%K 72	%K 73	sig	%P 72	%P 73	sig	Na mg/100g 72	Na mg/100g 73	sig	%Ca 72	%Ca 73	sig	%Mg 72	%Mg 73	sig	Mn mg/100g 72	Mn mg/100g 73	sig	Fe mg/100g 72	Fe mg/100g 73	sig	Cu mg/100g 72	Cu mg/100g 73	sig	B mg/100g 72	B mg/100g 73	sig	Zn mg/100g 72	Zn mg/100g 73	sig	Al mg/100g 72	Al mg/100g 73	sig
A. Spartansweet																																	
Muk Fm E	3.40	2.82	1%	0.59	0.50	5%	314	129	1%	0.19	0.24	NS	0.12	0.12	NS	0.10	1.90	5%	1.80	5.80	1%	0.04	0.87	NS	2.11	2.29	NS	0.40	2.60	5%	3.80	12.15	1%
Texas	2.74	2.18	5%	0.39	0.34	NS	237	262	NS	0.31	0.22	NS	0.12	0.09	5%	0.20	0.30	NS	2.80	4.15	NS	0.01	0.71	5%	1.84	1.78	NS	0	0.50	5%	14.55	8.20	NS
Idaho	2.18	2.00	5%	0.22	0.27	5%	244	152	1%	0.27	0.17	1%	0.08	0.09	NS	0.10	0.10	NS	1.65	2.90	1%	0.01	0.26	1%	1.84	1.65	1%	0	0.20	1%	6.00	4.20	5%
Im Cty	3.40	3.25	NS	0.42	0.47	NS	275	182	1%	0.02	0.13	NS	0.10	0.15	1%	0.10	1.05	NS	1.50	6.20	5%	0.47	0.75	NS	1.84	2.56	NS	0	2.25	5%	24.00	10.85	NS
Im Cty L	3.72	2.87	1%	0.46	0.49	NS	266	286	NS	0.33	0.15	NS	0.12	0.13	NS	0.60	1.90	NS	2.25	4.45	5%	0.47	0.55	NS	2.07	2.29	NS	0.95	0.65	NS	8.80	6.85	NS
Muk Fm L	3.58	2.26	NS	0.53	0.45	NS	227	387	NS	0.40	0.29	NS	0.13	0.11	NS	0.15	0.20	NS	4.67	3.55	NS	0.56	0.79	NS	2.13	2.11	NS	1.30	14.45	NS	6.65	0.10	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. Spartan Fancy																																	
Muk Fm E	--	3.05	--	--	0.51	--	---	137	--	--	0.19	--	--	0.13	--	--	0.40	--	--	4.60	--	--	0.59	--	--	2.01	--	--	1.40	--	---	6.85	--
Texas	1.48	2.15	NS	0.27	0.39	NS	146	284	NS	0.32	0.19	NS	0.11	0.09	1%	0.10	0.10	NS	2.25	4.75	NS	0.04	0.83	NS	1.84	1.83	NS	0.15	0.30	NS	12.30	14.70	NS
Idaho	1.62	1.80	NS	0.16	0.26	1%	129	155	NS	0.27	0.14	NS	0.08	0.07	NS	0.10	0.10	NS	2.35	3.20	NS	0.01	0.42	1%	1.84	1.46	NS	0.20	0	NS	12.60	5.30	NS
Im Cty	3.51	--	--	0.41	--	--	244	---	--	0.20	--	--	0.14	--	--	0.35	--	--	2.65	--	--	0.85	--	--	2.01	--	--	0.60	--	--	12.75	---	--
Im Cty L	3.30	2.39	NS	0.42	0.46	5%	237	235	NS	0.29	0.14	5%	0.11	0.10	NS	0.10	1.25	5%	2.40	4.00	NS	0.58	0.30	5%	2.11	2.29	NS	0.70	0.50	NS	9.15	1.00	5%
Muk Fm L	3.83	2.47	NS	0.54	0.51	5%	208	254	NS	0.34	0.29	NS	0.13	0.12	NS	0.10	0.30	NS	1.57	3.05	5%	0.01	0.84	1%	1.99	2.38	NS	1.22	1.55	NS	6.17	0.10	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
C. Spartan Delite																																	
Muk Fm E	--	3.10	--	--	0.48	--	---	151	--	--	0.18	--	--	0.12	--	--	0.65	--	--	5.35	--	--	0.71	--	--	2.06	--	--	1.70	--	---	20.25	--
Texas	3.15	2.22	5%	0.26	0.34	1%	171	242	NS	0.29	0.20	NS	0.12	0.09	NS	0.50	0.30	NS	2.90	5.65	5%	0.01	0.71	NS	1.97	2.06	NS	0.40	0.30	NS	14.80	12.70	NS
Idaho	1.90	2.00	NS	0.15	0.30	1%	131	152	5%	0.21	0.17	NS	0.09	0.08	1%	0.10	0.30	1%	2.65	3.70	5%	0.01	0.34	1%	1.84	1.65	1%	0	0.40	1%	8.55	0.10	1%
Im Cty	3.35	2.48	5%	0.40	0.44	NS	227	513	NS	0.18	0.20	NS	0.11	0.12	NS	0.10	1.60	1%	1.35	6.80	5%	0.82	0.84	NS	1.98	2.75	1%	2.70	2.70	NS	3.15	22.95	NS
Im Cty L	3.16	2.74	NS	0.40	0.44	NS	216	258	NS	0.41	0.10	1%	0.13	0.11	NS	0.75	0.80	NS	1.80	2.75	5%	0.51	0.17	1%	2.31	2.10	NS	1.25	0.40	NS	10.75	1.55	5%
Muk Fm L	3.52	2.70	NS	0.49	0.39	NS	175	203	NS	0.38	0.25	NS	0.12	0.11	NS	0.15	0.10	NS	1.80	3.05	NS	0.31	0.71	NS	2.09	2.15	NS	1.20	0.85	NS	4.72	0.10	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
D. Gold Pak																																	
Muk Fm E	3.67	2.92	NS	0.56	0.57	NS	236	146	5%	0.27	0.27	NS	0.16	0.14	5%	0.10	1.25	5%	1.80	9.60	NS	0.08	1.36	NS	2.51	2.20	NS	0.35	2.85	5%	4.75	14.30	NS
Texas	--	2.08	--	--	0.33	--	---	139	--	--	0.22	--	--	0.13	--	--	0.45	--	--	4.60	--	--	0.55	--	--	2.33	--	--	0.45	--	---	2.90	--
Idaho	--	1.68	--	--	0.28	--	---	114	--	--	0.19	--	--	0.10	--	--	0.10	--	--	4.00	--	--	0.26	--	--	1.83	--	--	0.40	--	---	0.50	--
Im Cty	3.67	2.91	5%	0.36	0.51	5%	172	243	NS	0.19	0.12	NS	0.13	0.12	NS	0.10	1.10	1%	1.65	5.20	5%	0.33	0.55	NS	2.04	2.20	NS	0	2.20	1%	23.35	7.95	NS
Im Cty L	3.77	2.78	NS	0.43	0.48	NS	204	182	NS	0.39	0.26	5%	0.15	0.14	NS	0.60	2.75	NS	2.67	5.50	NS	1.24	0.96	NS	2.49	2.70	NS	1.35	1.85	NS	20.50	3.40	NS
Muk Fm L	3.81	2.65	5%	0.48	0.55	NS	136	185	NS	0.38	0.36	NS	0.17	0.17	NS	0.10	0.95	5%	1.87	4.60	1%	0.17	1.28	5%	2.26	2.47	NS	1.60	2.70	NS	4.90	0.10	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance

Table 15. Canning Carrots, Proximate Analysis by Location

Variety	pH 72	pH 73	sig	% Nitrogen 72	% Nitrogen 73	sig	% Reducing Sugars 72	% Reducing Sugars 73	sig	% Total Sugars 72	% Total Sugars 73	sig	% Soluble Solids 72	% Soluble Solids 73	sig	% Total Solids 72	% Total Solids 73	sig
A. Muck Farm, Early Planting																		
Bonus	--	5.90	--	--	1.54	--	--	4.31	--	--	5.74	--	--	8.47	--	--	12.13	--
Danvers	--	5.70	--	--	1.49	--	--	4.23	--	--	5.32	--	--	7.43	--	--	12.15	--
sig		NS						NS			NS			NS			NS	
B. Texas																		
Bonus	6.49	6.31	1%	1.24	1.02	NS	1.92	1.84	NS	6.52	6.30	NS	8.05	9.15	5%	12.04	11.25	NS
Danvers	6.05	6.38	1%	1.18	1.03	NS	1.95	1.87	NS	6.07	6.07	NS	7.40	8.85	5%	11.25	10.80	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
C. Idaho																		
Bonus	6.50	6.30	1%	1.10	1.18	NS	2.47	1.24	1%	7.05	6.75	1%	9.25	9.60	NS	12.58	12.79	NS
Danvers	6.34	6.20	1%	0.93	0.84	NS	3.22	2.40	1%	6.17	5.70	1%	8.40	8.10	NS	11.46	11.36	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
D. Muck Farm, Late Planting																		
Bonus	6.04	6.12	NS	1.73	1.64	NS	2.38	0.71	1%	5.66	5.77	NS	8.77	7.05	5%	12.53	12.43	NS
Danvers	6.21	6.15	NS	1.89	1.55	NS	2.84	1.69	1%	4.65	4.57	NS	7.82	6.60	5%	11.27	10.82	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance

seasons were found, predominantly for pH, reducing sugar, and total sugar values. The pH values were relatively uniform between the two varieties. The Danvers variety had higher reducing sugar levels than Spartan Bonus. However, Spartan Bonus maintained higher values for total sugar, nitrogen, soluble solids, and total solids.

Table 16 shows the proximate analysis results for each variety. No significance was found between locations. As was found for the fresh market varieties, the pH levels of the Muck Farm, Early Planted samples were lower than the other locations. The Muck Farm, Late Planted group showed the highest nitrogen levels. Samples from no one location dominated for content of reducing sugars, total sugars, soluble solids, or total solids.

Vitamin assay results for samples from each location are shown in Table 17. For the Idaho location, a significant difference was found for the beta carotene values in the 1973 season; no other differences were found.

Roots of Spartan Bonus seemed to contain more of niacin and ascorbic acid. Neither variety dominated in content of other nutrients and the carotene values, in particular, were generally quite close.

No significance was found between samples from different locations for vitamin content (Table 18). The Muck Farm location appeared to produce roots with higher vitamin levels, although neither early nor late planting was favored.

Table 16. Canning Carrots, Proximate Analysis by Variety at Four Locations

Location	pH 72	pH 73	sig	% Nitrogen 72	% Nitrogen 73	sig	% Reducing Sugars 72	% Reducing Sugars 73	sig	% Total Sugars 72	% Total Sugars 73	sig	% Soluble Solids 72	% Soluble Solids 73	sig	% Total Solids 72	% Total Solids 73	sig
A. Spartan Bonus																		
Muk Fm E	--	5.90	--	--	1.54	--	--	4.31	--	--	5.74	--	--	8.47	--	--	12.13	--
Texas	6.49	6.31	1%	1.24	1.02	NS	1.92	1.84	NS	6.52	6.30	NS	8.05	9.15	5%	12.04	11.25	NS
Idaho	6.50	6.30	1%	1.10	1.18	NS	2.47	1.24	1%	7.05	6.75	1%	9.25	9.60	NS	12.58	12.79	NS
Muk Fm L	6.04	6.12	NS	1.73	1.64	NS	2.38	0.71	1%	5.66	5.77	NS	8.77	7.05	5%	12.53	12.43	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. Danvers																		
Muk Fm E	--	5.70	--	--	1.49	--	--	4.23	--	--	5.32	--	--	7.43	--	--	12.15	--
Texas	6.05	6.38	1%	1.18	1.03	NS	1.95	1.87	NS	6.07	6.07	NS	7.40	8.85	5%	11.25	10.80	NS
Idaho	6.34	6.20	1%	0.93	0.84	NS	3.22	2.40	1%	6.17	5.70	1%	8.40	8.10	NS	11.46	11.36	NS
Muk Fm L	6.21	6.15	NS	1.89	1.55	NS	2.84	1.69	1%	4.65	4.57	NS	7.82	6.60	5%	11.27	10.82	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance

Table 17. Canning Carrots, Vitamin Assay by Location

Table 17. Canning Carrots, Vitamin Assay by Location

Variety	Riboflavin ug/g 72*	73**	sig	Thiamin ug/g 72	73	sig	Niacin ug/g 72	73	sig	Ascorbic Acid mg/100g 72	73	sig	Carotenes, mg/g Total 72	73	sig	Beta 72	73	sig
A. Muck Farm, Early Planting																		
Bonus	--	0.63	--	--	1.06	--	--	2.74	--	--	10.79	--	--	0.17	--	--	0.15	--
Danvers	--	0.77	--	--	1.14	--	--	3.51	--	--	8.47	--	--	0.17	--	--	0.14	--
sig		NS			NS			NS			NS			NS			NS	
B. Texas																		
Bonus	0.44	0.46	NS	1.16	0.55	5%	2.94	1.84	1%	9.63	8.06	1%	0.17	0.15	NS	0.15	0.14	NS
Danvers	0.52	0.47	NS	1.20	0.60	5%	2.50	1.46	1%	4.96	7.35	1%	0.15	0.16	NS	0.14	0.15	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
C. Idaho																		
Bonus	0.89	0.50	1%	0.75	0.73	NS	7.46	1.73	1%	8.44	10.10	1%	0.16	0.16	NS	0.15	0.15	NS
Danvers	0.39	0.29	NS	0.62	0.67	NS	7.16	1.45	1%	6.19	7.72	1%	0.13	0.11	NS	0.12	0.09	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	5%	
D. Muck Farm, Late Planting																		
Bonus	0.74	0.59	NS	0.96	1.19	NS	7.99	2.54	1%	9.02	8.55	NS	0.19	0.21	NS	0.18	0.19	NS
Danvers	0.62	0.36	NS	0.98	1.33	NS	6.64	1.85	1%	7.30	7.57	NS	0.20	0.18	NS	0.17	0.17	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance
* = growing season 1972
** = growing season 1973

Table 18. Canning Carrots, Vitamin Assay by Variety at Four Locations

Table 18. Canning Carrots, Vitamin Assay by Variety at Four Locations

Location	Riboflavin ug/g 72*	73**	sig	Thiamin ug/g 72	73	sig	Niacin ug/g 72	73	sig	Ascorbic Acid mg/100g 72	73	sig	Carotenes Total 72	73	sig	Beta 72	73	sig
A. Spartan Bonus																		
Muk Fm E	--	0.63	--	--	1.06	--	--	2.74	--	--	10.79	--	--	0.17	--	--	0.15	--
Texas	0.44	0.46	NS	1.16	0.55	5%	2.94	1.84	1%	9.63	8.06	1%	0.17	0.15	NS	0.15	0.14	NS
Idaho	0.89	0.50	1%	0.75	0.73	NS	7.46	1.73	1%	8.44	10.10	1%	0.16	0.16	NS	0.15	0.15	NS
Muk Fm L	0.74	0.59	NS	0.96	1.19	NS	7.99	2.54	1%	9.02	8.55	NS	0.19	0.21	NS	0.18	0.19	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. Danvers																		
Muk Fm E	--	0.77	--	--	1.14	--	--	3.51	--	--	8.47	--	--	0.17	--	--	0.14	--
Texas	0.52	0.47	NS	1.20	0.60	5%	2.50	1.46	1%	4.96	7.35	1%	0.15	0.16	NS	0.14	0.15	NS
Idaho	0.39	0.29	NS	0.62	0.67	NS	7.16	1.45	1%	6.19	7.72	1%	0.13	0.11	NS	0.12	0.09	NS
Muk Fm L	0.62	0.36	NS	0.98	1.33	NS	6.64	1.85	1%	7.30	7.57	NS	0.20	0.18	NS	0.17	0.17	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance
* = growing season 1972
** = growing season 1973

Several differences were found for nutrient content of roots grown in different growing seasons. Unlike the fresh market variety Spartansweet, neither of the canning varieties appeared to be affected by different growing seasons.

As shown in Table 19, mineral elements were generally accumulated equally by both canning varieties. Significance was shown at the Idaho location in the 1973 growing season for root content of phosphorous and sodium, but no other differences between varieties were noted. Neither variety showed a tendency to accumulate higher levels of any element.

Several differences between years were found. Texas, Idaho, and the Muck Farm, late planting all showed seasonal differences for potassium levels. Additionally, Texas showed differences for calcium levels and Idaho showed differences for phosphorous, calcium, iron and copper levels.

No differences were found between locations (Table 20). The roots grown at the Muck Farm locations seemed to accumulate higher mineral levels. This trend was also noted for the vitamin analyses. Spartan Bonus showed the greatest changes between seasons in the potassium, copper, and to a lesser extent, calcium levels. Potassium and calcium levels were lower in 1973 and copper levels were higher.

It appears that Spartan Bonus is the overall better variety for nutritional composition since it equalled or bettered the Danvers variety in all categories but reducing sugars. Although not statistically different, the Muck Farm locations tended to show a better nutrient content for both of the varieties than other locations.

Table 19. Canning Carrots, Mineral Levels by Location

	%K			%P			Na mg/100g			%Ca			%Mg			Mn mg/100g			Fe mg/100g			Cu mg/100g			B mg/100g			Zn mg/100g			Al mg/100g		
	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig
A. Muck Farm, Early Planting																																	
Bonus	—	3.25	—	—	0.49	—	—	215	—	—	0.21	—	—	0.14	--	—	0.70	--	—	5.75	—	—	0.80	—	—	2.11	—	—	1.30	—	—	10.05	--
Danvers	—	3.56	—	—	0.49	—	—	168	—	—	0.29	--	—	0.15	--	—	2.30	--	—	5.65	--	--	1.00	—	—	2.70	—	—	2.85	—	—	7.10	—
sig		NS			NS			NS			NS			NS			NS			NS			NS			NS			NS			NS	
B. Texas																																	
Bonus	3.05	2.22	1%	0.41	0.34	5%	302	220	1%	0.42	0.17	1%	0.14	0.13	NS	2.70	0.30	5%	2.65	3.60	NS	0.01	0.30	NS	2.41	2.33	NS	0.75	0.20	NS	13.25	2.35	NS
Danvers	3.05	2.34	5%	0.29	0.28	NS	298	224	NS	0.34	0.17	5%	.14	0.09	NS	0.60	0.10	NS	2.65	3.30	NS	0.01	0.34	1%	2.04	1.78	NS	0.15	0.30	NS	10.40	3.20	5%
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
C. Idaho																																	
Bonus	2.66	1.88	1%	0.23	0.30	1%	180	127	NS	0.27	0.14	1%	0.11	0.10	NS	0.35	0.10	NS	2.65	3.40	5%	0.01	0.67	1%	1.94	1.83	NS	0.65	0.20	NS	7.60	0.10	1%
Danvers	2.52	1.88	5%	0.19	0.23	1%	219	255	NS	0.27	0.19	1%	0.08	0.08	NS	0.10	0.50	1%	2.25	4.60	1%	0.01	1.16	1%	1.87	1.83	NS	0	0.60	1%	9.80	18.10	NS
sig	NS	NS		NS	5%		NS	5%		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
D. Muck Farm, Late Planting																																	
Bonus	3.62	1.94	5%	0.40	0.39	NS	220	299	NS	0.43	0.25	5%	0.14	0.14	NS	0.75	0.30	NS	2.00	3.00	NS	0.26	0.71	NS	2.45	2.19	NS	1.20	1.20	NS	8.37	0.10	NS
Danvers	4.43	2.04	5%	0.54	0.38	NS	204	605	5%	0.39	0.31	NS	0.15	0.13	NS	0.22	0.80	NS	1.65	4.45	NS	0.01	1.32	1%	2.08	2.10	NS	1.05	1.95	NS	3.47	4.80	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance

Table 20. Canning Carrots, Mineral Levels by Variety at Four Locations

Location	%K 72	%K 73	sig	%P 72	%P 73	sig	Na mg/100g 72	Na mg/100g 73	sig	%Ca 72	%Ca 73	sig	%Mg 72	%Mg 73	sig	Mn mg/100g 72	Mn mg/100g 73	sig	Fe mg/100g 72	Fe mg/100g 73	sig	Cu mg/100g 72	Cu mg/100g 73	sig	B mg/100g 72	B mg/100g 73	sig	Zn mg/100g 72	Zn mg/100g 73	sig	Al mg/100g 72	Al mg/100g 73	sig
A. Spartan Booms																																	
Muk Fm E	—	3.25	—	—	0.49	—	—	215	—	—	0.21	—	—	0.14	—	—	0.70	—	—	5.75	—	—	0.80	—	—	2.11	—	—	1.30	—	—	10.05	—
Texas	3.05	2.22	1%	0.41	0.34	5%	302	220	1%	0.42	0.17	1%	0.14	0.13	NS	2.70	0.30	5%	2.65	3.60	NS	0.01	0.30	NS	2.41	2.33	NS	0.75	0.20	NS	13.25	2.35	NS
Idaho	2.66	1.88	1%	0.23	0.30	1%	180	127	NS	0.27	0.14	1%	0.11	0.10	NS	0.35	0.10	NS	2.65	3.40	5%	0.01	0.67	1%	1.94	1.83	NS	0.65	0.20	NS	7.60	0.10	1%
Muk Fm L	3.62	1.94	5%	0.40	0.39	NS	220	299	NS	0.43	0.25	5%	0.14	0.14	NS	0.75	0.30	NS	2.00	3.00	NS	0.26	0.71	NS	2.45	2.19	NS	1.20	1.20	NS	8.37	0.10	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. Danvers																																	
Muk Fm E	—	3.56	—	—	0.49	—	—	168	—	—	0.29	—	—	0.15	—	—	2.30	—	—	5.65	—	—	1.00	—	—	2.70	—	—	2.85	—	—	7.10	—
Texas	3.05	2.34	5%	0.29	0.28	NS	298	244	NS	0.34	0.17	5%	0.14	0.09	NS	0.60	0.10	NS	2.65	3.30	NS	0.01	0.34	1%	2.04	1.78	NS	0.15	0.30	NS	10.40	3.20	5%
Idaho	2.52	1.88	5%	0.19	0.23	1%	219	255	NS	0.27	0.19	1%	0.08	0.08	NS	0.10	0.50	1%	2.25	4.60	1%	0.01	1.16	1%	1.87	1.83	NS	0	0.60	1%	9.80	18.10	NS
Muk Fm L	4.43	2.04	5%	0.54	0.38	NS	204	605	5%	0.39	0.31	NS	0.15	0.13	NS	0.22	0.80	NS	1.65	4.45	NS	0.01	1.32	1%	2.08	2.10	NS	1.05	1.95	NS	3.47	4.80	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance

Parent Lines

The results of analyses for the parent lines of the Spartan varieties are found in Tables 21-29. These tables are summarized as mean values presented in Tables 32-35.

Samples of roots of the parent lines were obtained in both years of the study from Texas, Idaho, and the Muck Farm, Late Planting. The Muck Farm, Early Planting provided samples only in the 1973 season, but these data are included here for comparative purposes.

Table 21 contains the proximate analysis results obtained for the samples from the Muck Farm, Early and Late Plantings. No significant differences were found among varieties. The pH and nitrogen values remained relatively constant over the two growing seasons. Reducing sugars, total sugars, soluble solids, and total solids were all lower in the 1973 season. The wet growing conditions at the Muck Farm in 1973 contributed to the results.

The proximate analysis of the roots from Texas and Idaho did show some significant differences between varieties (Table 22). Total sugar levels of roots from Texas were statistically different in both years of the study. The 1972 season showed differences in total sugars between MSU 6000 and MSU 5986. 1973 samples showed differences in total sugars between MSU 6000 and MSU 5931. Missing data from MSU 5931 in the 1972 season would have probably proved to be significantly different also since this variety was consistently low with respect to the other analyses listed in Table 22.

Table 21. Parent Lines of Spartan Carrot Varieties, Proximate Analysis of Muck Farm, Early Planted and Muck Farm, Late Planted Samples

Variety	pH			% Nitrogen			% Reducing Sugars			% Total Sugars			% Soluble Solids			% Total Solids		
	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig
A. Muck Farm, Early Planting																		
872	--	5.94	--	--	1.66	--	--	4.01	--	--	5.62	--	--	9.60	--	--	13.11	--
5931	--	5.75	--	--	1.77	--	--	4.40	--	--	5.70	--	--	9.30	--	--	13.76	--
6000	--	5.82	--	--	1.78	--	--	4.72	--	--	5.92	--	--	6.75	--	--	13.35	--
9541	--	5.84	--	--	1.73	--	--	4.31	--	--	4.65	--	--	5.85	--	--	11.74	--
5986	--	5.80	--	--	1.71	--	--	4.18	--	--	5.70	--	--	7.33	--	--	13.43	--
sig		NS			NS			NS			NS			NS			NS	
B. Muck Farm, Late Planting																		
872	6.05	6.32	5%	1.88	2.09	NS	1.99	0.60	1%	6.00	5.70	NS	9.72	6.90	1%	13.53	12.36	NS
5931	5.99	6.00	NS	1.81	1.70	NS	2.48	0.41	1%	6.21	5.10	1%	9.85	8.40	NS	13.76	10.80	1%
6000	6.13	6.20	NS	1.81	1.61	NS	3.22	0.56	1%	7.08	5.47	1%	11.17	9.00	5%	15.34	13.03	1%
9541	6.15	6.20	NS	1.82	2.22	NS	3.33	0.81	1%	5.59	4.95	5%	8.50	8.40	NS	12.45	11.75	NS
5986	6.07	5.99	NS	2.05	1.99	NS	1.79	0.86	NS	5.44	4.91	NS	9.35	6.75	5%	13.11	11.27	5%
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance

Table 22. Parent Lines of Spartan Carrot Varieties, Proximate Analysis of Texas and Idaho Samples

Variety	pH 72	pH 73	sig	% Nitrogen 72	% Nitrogen 73	sig	% Reducing Sugars 72	% Reducing Sugars 73	sig	% Total Sugars 72	% Total Sugars 73	sig	% Soluble Solids 72	% Soluble Solids 73	sig	% Total Solids 72	% Total Solids 73	sig
A. Texas																		
6000	6.50	6.10	1%	1.40	1.05	5%	1.80	1.80	NS	6.75	6.67	NS	8.60	9.90	1%	13.07	12.18	5%
872	6.05	6.22	5%	1.45	1.21	5%	2.03	1.35	1%	6.35	6.07	NS	8.90	9.00	NS	11.45	11.87	NS
9541	6.10	6.25	1%	1.22	1.19	NS	2.17	2.02	5%	5.55	5.70	NS	8.20	7.80	NS	10.85	10.71	NS
5986	6.06	6.10	NS	1.26	0.94	NS	2.05	1.91	NS	5.10	5.92	1%	8.50	8.25	NS	12.35	11.58	NS
5931	--	6.10		--	1.02	--	--	1.59	--	--	4.95	--	--	6.60	--	---	10.59	--
sig	NS	NS		NS	NS		NS	NS		5%	5%		NS	NS		NS	NS	
B. Idaho																		
9541	6.20	6.30	1%	0.90	1.08	1%	2.81	3.00	1%	6.22	6.60	5%	9.00	8.70	NS	11.65	12.27	1%
872	6.30	6.20	1%	1.00	0.94	NS	2.61	2.55	NS	6.15	6.60	1%	8.70	8.40*	NS	11.35	12.63	1%
6000	6.13	6.30	5%	0.90	1.08	1%	3.00	2.32	1%	7.45	7.35	NS	9.60	10.35*	5%	13.17	13.35	NS
5986	6.26	6.20	NS	0.86	0.98	5%	2.26	1.80	1%	6.15	7.05	1%	8.33	9.30	1%	11.73	12.41	1%
5931	6.24	6.15	NS	1.01	1.14	1%	2.62	0.94	1%	6.95	6.30	1%	9.05	9.17	NS	11.73	12.33	1%
sig	NS	NS		NS	NS		NS	5%		NS	NS		NS	5%		NS	NS	

* Significance between varieties 872 and 6000
NS = No Significance

Samples from Idaho showed differences in reducing sugars and soluble solids. MSU 9541 and MSU 5931 were significantly different in reducing sugars, and MSU 6000 and MSU 872 proved significantly different in soluble solids. Although differences were noted between years, the pH and nitrogen values were relatively constant. In the other categories, MSU 6000 again ranked very high. No one variety showed consistently low values as was true of MSU 5931 at Texas.

No difference in proximate analyses were found between carrot roots of the different locations (Table 23). The Early planted samples from the Muck Farm had lower pH values than the other locations, a condition which was also noted in the roots of the canning lines. The Muck Farm samples also contained generally high nitrogen and total solids levels. Root content of reducing sugar, total sugar, and soluble solids was generally high from samples representative of the Idaho location. This trait was also observed in the fresh market and canning lines.

Vitamin assay of the Muck Farm, Early and Late Planted samples showed several differences between varieties (Table 24). MSU 6000 and MSU 9541 were significantly different in thiamin content, for the early planted samples. No other differences were found in the early planted samples, but MSU 6000 did maintain the highest levels in all vitamins assayed.

The late planted samples showed differences in thiamin, total carotene, and beta-carotene levels. No other differences

Table 23. Parent Lines of Spartan Carrot Varieties, Proximate Analysis by Variety at Four Locations

Location	pH 72	pH 73	sig	% Nitrogen 72	% Nitrogen 73	sig	% Reducing Sugars 72	% Reducing Sugars 73	sig	% Total Sugars 72	% Total Sugars 73	sig	% Soluble Solids 72	% Soluble Solids 73	sig	% Total Solids 72	% Total Solids 73	sig
A. MSU 872																		
Muk Fm E	—	5.94	—	—	1.66	—	—	4.01	—	—	5.62	—	—	9.60	—	—	13.11	—
Texas	6.05	6.22	5%	1.45	1.21	5%	2.03	1.35	1%	6.35	6.07	NS	8.90	9.00	NS	11.45	11.87	NS
Idaho	6.30	6.20	1%	1.00	0.94	NS	2.61	2.55	NS	6.15	6.60	1%	8.70	8.40	NS	11.35	12.63	1%
Muk Fm L	6.05	6.32	5%	1.88	2.09	NS	1.99	0.60	1%	6.00	5.70	NS	9.72	6.90	5%	13.53	12.36	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. MSU 5931																		
Muk Fm E	—	5.75	—	—	1.77	—	—	4.40	—	—	5.70	—	—	9.30	—	—	13.76	—
Texas	—	6.10	—	—	1.02	—	—	1.59	—	—	4.95	—	—	6.60	—	—	10.59	—
Idaho	6.24	6.15	NS	1.01	1.14	1%	2.62	0.94	1%	6.95	6.30	1%	9.05	9.17	NS	11.73	12.33	1%
Muk Fm L	5.99	6.00	NS	1.81	1.70	NS	2.48	0.41	1%	6.21	5.10	1%	9.85	8.40	NS	13.76	10.80	1%
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
C. MSU 6000																		
Muk Fm E	—	5.82	—	—	1.78	—	—	4.72	—	—	5.92	—	—	6.75	—	—	13.35	—
Texas	6.50	6.10	1%	1.40	1.05	5%	1.80	1.80	NS	6.75	6.67	NS	8.60	9.90	1%	13.07	12.18	5%
Idaho	6.13	6.30	5%	0.90	1.08	1%	3.00	2.32	1%	7.45	7.35	NS	9.60	10.33	5%	13.17	13.35	NS
Muk Fm L	6.13	6.20	NS	1.81	1.61	NS	3.22	0.56	1%	7.08	5.47	1%	11.17	9.00	5%	15.34	13.03	1%
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
D. MSU 9541																		
Muk Fm E	—	5.84	—	—	1.73	—	—	4.31	—	—	4.65	—	—	5.85	—	—	11.74	—
Texas	6.10	6.25	NS	1.22	1.19	NS	2.17	2.02	5%	5.55	5.70	NS	8.20	7.80	NS	10.85	10.71	NS
Idaho	6.20	6.30	1%	0.90	1.08	1%	2.81	3.00	1%	6.22	6.60	5%	9.00	8.70	NS	11.65	12.27	1%
Muk Fm L	6.15	6.20	NS	1.82	2.22	NS	3.33	0.81	1%	5.59	4.95	5%	8.50	8.40	NS	12.45	11.75	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
E. MSU 5986																		
Muk Fm E	—	5.89	—	—	1.71	—	—	4.18	—	—	5.70	—	—	7.33	—	—	13.43	—
Texas	6.06	6.10	1%	1.26	0.94	1%	2.05	1.91	NS	5.10	5.92	1%	8.50	8.25	NS	12.35	11.58	NS
Idaho	6.26	6.20	NS	0.86	0.98	5%	2.26	1.80	1%	6.15	7.05	1%	8.33	9.30	1%	11.73	12.41	1%
Muk Fm L	6.07	5.99	NS	2.05	1.99	NS	1.79	0.86	NS	5.44	4.91	NS	9.35	6.75	5%	13.11	11.27	5%
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance

Table 24. Parent Lines of Spartan Carrot Varieties, Vitamin Assay of Muck Farm, Early Planted and Muck Farm Late Planted Samples

Variety	Riboflavin ug/g 72	73	sig	Thiamin ug/g 72	73	sig	Niacin ug/g 72	73	sig	Ascorbid Acid mg/100g 72	73	sig	Carotenes, mg/g Total 72	73	sig	Beta 72	73	sig
A. Muck Farm, Early Planting																		
6000	--	1.07	--	--	1.66	--	--	3.59	--	--	14.27	--	--	0.24	--	--	0.23	--
5986	--	0.84	--	--	1.31	--	--	3.25	--	--	11.42	--	--	0.20	--	--	0.19	--
5931	--	0.78	--	--	1.20	--	--	3.43	--	--	14.17	--	--	0.15	--	--	0.15	--
872	--	0.87	--	--	1.06	--	--	2.61	--	--	9.26	--	--	0.19	--	--	0.18	--
9541	--	0.62	--	--	0.89	--	--	3.23	--	--	8.45	--	--	0.18	--	--	0.19	--
sig		NS			5%			NS			NS			NS			NS	
B. Muck Farm, Late Planting																		
6000	1.36	0.92	NS	1.90	2.88*	1%	8.45	3.35	1%	10.78	7.00	1%	0.32	0.34	5%	0.30	0.31	NS
872	0.91	0.70	NS	0.95	0.92*	NS	6.30	3.39	NS	5.35	5.35	NS	0.22	0.26	NS	0.19	0.24	NS
9541	0.77	0.67	NS	0.89	1.39	NS	6.61	1.86	1%	10.19	7.52	NS	0.24	0.22	NS	0.22	0.20	NS
5986	0.84	0.56	NS	1.52	1.64	NS	6.12	3.53	NS	9.27	4.93	1%	0.23	0.21	NS	0.23	0.19	NS
5931	0.73	0.44	NS	1.13	1.17	NS	7.23	3.37	NS	8.39	9.15	NS	0.18	0.14	NS	0.18	0.13	NS
sig	NS	NS		NS	5%		NS	NS		NS	NS		NS	5%		NS	5%	

* Significance between varieties 6000 and 872

NS = No Significance

were noted between varieties. MSU 6000 again showed high levels of all vitamins as noted in the early planted samples.

Differences between seasons occurred in niacin, ascorbic acid, thiamin, and total carotene content. The late planted samples appear stable from season to season for nutrient content of roots of the parent lines. The root analyses of late planted samples were also seasonally stable for both fresh market and canning varieties (Tables 3, 7, 11, 15, 17, and 19).

Vitamin results for the samples from the Texas and Idaho locations are shown in Table 25. Significance was found at the Texas location between varieties in total and beta carotenes. Total carotene differences were found between MSU 872 and MSU 5931, but only in the 1973 season. Beta carotene differences were found between MSU 6000 and MSU 5986 in the 1972 season. MSU 6000 produced carotenes well at Texas, but did not predominate in the other vitamins.

Varietal differences at the Idaho location were found for thiamin and beta carotene content (Table 25). MSU 6000 and MSU 872 were significantly different in thiamin levels for the 1973 season. MSU 6000 and MSU 5931 were significantly different in beta-carotene levels, also for the 1973 season. MSU 6000 performed well at the Idaho location in all vitamin categories but niacin.

Several seasonal differences were found for the samples grown at the locations shown in Table 25. Generally, the samples from the 1973 season showed lower vitamin levels than the samples from the 1972 season.

Table 25. Parent Lines of Spartan Carrot Varieties, Vitamin Assay of Texas and Idaho Samples

Variety	Riboflavin ug/g			Thiamin ug/g			Niacin ug/g			Ascorbic Acid mg/100g			Carotenes, mg/g Total			Carotenes, mg/g Beta		
	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig
A. Texas																		
872	0.62	0.65	NS	1.06	0.70	NS	3.66	2.54	5%	7.84	7.58	NS	0.17	0.17	NS	0.16	0.16	NS
6000	0.56	0.52	1%	1.05	0.91	NS	4.10	2.20	5%	9.79	9.44	NS	0.22	0.16	5%	0.21*	0.14	1%
9541	0.77	0.53	5%	1.00	0.66	NS	3.16	2.29	5%	11.23	10.28	NS	0.19	0.16	5%	0.18	0.15	5%
5986	0.59	0.36	5%	1.55	1.01	5%	4.28	1.82	5%	10.11	8.75	5%	0.16	0.16	NS	0.14*	0.15	NS
5931	--	0.38	--	--	0.68	--	--	1.66	--	--	5.67	--	--	0.10	--	--	0.10	--
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	5%		5%*	NS	
B. Idaho																		
6000	0.88	0.80	NS	0.88	1.21	NS	6.35	2.00	1%	10.64	13.21	1%	0.20	0.18	5%	0.20	0.16[a]	5%
5931	0.43	0.41	NS	0.66	0.96	NS	7.43	2.02	1%	6.84	12.91	1%	0.12	0.08	1%	0.12	0.08[a]	1%
5986	0.63	0.62	NS	0.72	0.79	NS	5.42	1.27	1%	9.19	11.42	1%	0.14	0.14	NS	0.13	0.13	NS
9541	0.53	0.52	NS	0.44	0.56	NS	5.93	0.95	1%	9.77	9.85	NS	0.18	0.15	1%	0.17	0.13	1%
872	0.67	0.62	NS	0.47	0.38	NS	6.62	1.43	1%	5.85	7.93	1%	0.17	0.18	NS	0.16	0.15	5%
sig	NS	NS		NS	5%		NS	NS		NS	NS		NS	NS		NS	5%	

* Significance between varieties 6000 and 5986

[a] Significance between varieties 6000 and 5931

NS = No Significance

Table 26 shows that location did not significantly influence vitamin production in the carrot samples. Samples from the Muck Farm location were generally higher in vitamin production than samples from other locations. Early planted roots favored production of riboflavin and ascorbic acid while carotene production was stimulated in late planted roots. These results support the findings of other workers in that the growth of late planted varieties would be subjected to lower temperatures during root development and thus produce higher levels of carotenes. Thiamin and niacin did not seem affected by planting date.

Varietal comparisons in Tables 24 and 25 showed MSU 6000 to be high in vitamin production. Table 26 shows that MSU 6000 is also more sensitive to seasonal changes in its vitamin production. A higher number of significant differences was noted between years for MSU 6000 than for other varieties.

Mineral levels of the roots from the early and late Muck Farm plantings are shown in Table 27. No significant differences among varieties were found. No one variety dominated in accumulation of mineral elements and MSU 6000, which was high in sugars and vitamins, was generally low in mineral content.

Table 28 shows several differences between varieties. At the Texas location MSU 872 and MSU 6000 were significantly different in calcium and zinc levels in the 1973 season. At the Idaho location roots of MSU 9451 and MSU 6000 were significantly different in potassium and iron in the 1973 season. As in Table 27, no one variety dominated in high mineral

Table 26. Parent Lines of Spartan Carrot Varieties, Vitamin Assay by Variety at Four Locations

Location	Riboflavin ug/g			Thiamin ug/g			Niacin ug/g			Ascorbic Acid mg/100g			Carotenes, mg/g Total			Carotenes, mg/g Beta		
	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig
A. MSU 872																		
Muk Fm E	--	0.87	--	--	1.06	--	--	2.61	--	--	9.26	--	--	0.19	--	--	0.18	--
Texas	0.62	0.65	NS	1.06	0.70	NS	3.66	2.54	5%	7.84	7.58	NS	0.17	0.17	NS	0.16	0.16	NS
Idaho	0.67	0.62	NS	0.47	0.38	NS	6.62	1.43	1%	5.85	7.93	1%	0.17	0.18	NS	0.16	0.15	5%
Muk Fm L	0.91	0.91	NS	0.85	0.92	NS	6.30	3.39	NS	5.35	5.35	NS	0.22	0.26	NS	0.19	0.24	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. MSU 5931																		
Muk Fm E	--	0.78	--	--	1.20	--	--	3.46	--	--	14.17	--	--	0.15	--	--	0.15	--
Texas	--	0.38	--	--	0.68	--	--	1.66	--	--	5.67	--	--	0.10	--	--	0.10	--
Idaho	0.43	0.41	NS	0.66	0.96	NS	7.43	2.02	1%	6.84	12.91	1%	0.12	0.08	1%	0.12	0.08	1%
Muk Fm L	0.73	0.44	NS	1.13	1.17	NS	7.23	3.37	NS	8.39	9.15	NS	0.18	0.14	NS	0.18	0.13	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
C. MSU 6000																		
Muk Fm E	--	1.07	--	--	1.66	--	--	3.59	--	--	14.27	--	--	0.24	--	--	0.23	--
Texas	0.56	0.52	1%	1.05	0.91	NS	4.10	2.20	5%	9.79	9.44	NS	0.22	0.16	5%	0.21	0.14	1%
Idaho	0.88	0.80	NS	0.88	1.21	NS	6.35	2.00	1%	10.64	13.21	1%	0.20	0.18	5%	0.20	0.16	5%
Muk Fm L	1.36	0.92	NS	1.90	2.88	1%	8.45	3.35	1%	10.78	7.00	1%	0.32	0.34	5%	0.30	0.31	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
D. MSU 9541																		
Muk Fm E	--	0.62	--	--	0.89	--	--	3.32	--	--	8.45	--	--	0.18	--	--	0.19	--
Texas	0.77	0.53	5%	1.00	0.66	NS	3.16	2.29	5%	11.23	10.28	NS	0.19	0.16	5%	0.18	0.15	5%
Idaho	0.53	0.52	NS	0.44	0.56	NS	5.93	0.95	1%	9.77	9.85	NS	0.18	0.15	1%	0.17	0.13	1%
Muk Fm L	0.77	0.67	NS	0.89	1.39	NS	6.61	1.86	1%	10.12	7.52	NS	0.24	0.22	NS	0.22	0.20	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS				
E. MSU 5986																		
Muk Fm E	--	0.84	--	--	1.31	--	--	3.25	--	--	11.42	--	--	0.20	--	--	0.19	--
Texas	0.59	0.36	5%	1.55	1.01	5%	4.28	1.82	5%	10.11	8.75	5%	0.16	0.16	NS	0.14	0.15	NS
Idaho	0.63	0.62	NS	0.72	0.79	NS	5.42	1.27	1%	9.19	11.42	5%	0.14	0.14	NS	0.13	0.13	NS
Muk Fm L	0.84	0.56	NS	1.52	1.64	NS	6.12	3.53	NS	9.27	4.93	5%	0.23	0.21	NS	0.23	0.19	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance

Table 27. Parent Lines of Spartan Carrot Varieties, Mineral Analysis of Muck Farm, Early Planted and Muck Farm, Late Planted Samples

Variety	%K			%P			Na mg/100g			%Ca			%Mg			Mn mg/100g			Fe mg/100g			Cu mg/100g			B mg/100g			Zn mg/100g			Al mg/100g		
	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig
A. Muck Farm, Early Planting																																
872	—	3.30	—	—	0.49	—	—	158	—	—	0.25	—	—	0.14	—	—	1.90	—	—	5.05	—	—	0.88	—	—	2.52	—	—	2.50	—	—	8.45	—
5931	—	3.70	—	—	0.56	—	—	202	—	—	0.25	—	—	0.13	—	—	1.05	—	—	5.05	—	—	0.87	—	—	2.20	—	—	2.15	—	—	10.60	—
6000	—	3.30	—	—	0.53	—	—	147	—	—	0.13	—	—	0.13	—	—	0.70	—	—	4.75	—	—	0.75	—	—	2.01	—	—	1.95	—	—	12.20	—
9541	—	3.45	—	—	0.50	—	—	228	—	—	0.23	—	—	0.18	—	—	1.75	—	—	5.50	—	—	0.84	—	—	2.84	—	—	2.20	—	—	11.35	—
5986	—	3.35	—	—	0.51	—	—	206	—	—	0.24	—	—	0.12	—	—	1.40	—	—	4.75	—	—	0.75	—	—	2.47	—	—	2.40	—	—	7.35	—
sig		NS			NS			NS			NS			NS			NS			NS			NS			NS			NS			NS	
B. Muck Farm, Late Planting																																
872	3.32	2.56	NS	0.46	0.45	NS	189	258	NS	0.40	0.28	NS	0.16	0.13	NS	0.52	0.60	NS	1.85	2.15	NS	6.10	5.45	NS	2.16	2.20	NS	0.90	0.85	NS	11.05	0.10	NS
5931	3.56	2.92	1%	0.51	0.52	NS	245	345	NS	0.42	0.29	NS	0.14	0.11	5%	0.47	0.45	NS	2.25	3.15	NS	3.62	4.20	NS	2.21	2.33	NS	1.42	1.30	NS	13.10	0.10	NS
6000	3.10	2.56	NS	0.49	0.50	NS	118	140	NS	0.36	0.23	NS	0.13	0.13	NS	0.10	0.30	NS	1.57	2.75	NS	0.02	0.59	5%	1.84	1.92	NS	1.82	1.40	NS	5.87	0.10	NS
9541	3.45	2.34	5%	0.45	0.49	NS	222	433	NS	0.32	0.23	NS	0.15	0.14	NS	0.15	0.30	NS	1.65	3.00	NS	0.01	1.20	NS	2.27	2.79	5%	0.65	1.20	NS	8.67	2.15	NS
5986	4.02	2.19	5%	0.52	0.54	NS	226	484	1%	0.41	0.29	NS	0.12	0.13	1%	0.10	0.10	NS	2.40	3.70	5%	0.31	0.42	NS	2.36	2.47	NS	1.72	0.90	NS	14.50	0.10	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance

Table 28. Parent Lines of Spartan Carrot Varieties, Mineral Levels of Texas and Idaho

Variety	%K			%P			Na mg/100g			%Ca			%Mg			Mn mg/100g			Fe mg/100g			Cu mg/100g			B mg/100g			Zn mg/100g			Al mg/100g		
	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig	72	73	sig
A. Texas																																	
872	3.05	2.24	NS	0.36	0.33	NS	251	241	NS	0.33	0.25	NS	0.17	0.15	NS	0.60	1.05	NS	2.80	3.75	NS	0.01	0.92	1%	2.24	2.10	NS	0.85	0.65	NS	13.25	9.00	NS
5931	--	2.48	--	--	0.39	--	---	229	--	--	0.21	--	--	0.10	--	--	0.30	--	--	5.20	--	--	0.42	--	--	2.29	--	--	0.45	--	---	6.30	--
9541	3.67	3.01	NS	0.31	0.39	5%	221	229	NS	0.32	0.19	5%	0.17	0.14	NS	1.70	0.65	NS	3.65	4.60	5%	0.01	0.46	1%	2.77	2.61	NS	0.90	0.40	NS	17.05	3.20	NS
5986	2.78	2.43	NS	0.43	0.33	5%	246	200	NS	0.29	0.17	NS	0.12	0.09	NS	0.10	0.45	NS	3.50	3.70	NS	0.01	0.34	NS	2.24	2.34	NS	0.15	0.45	NS	14.80	6.35	NS
6000	1.82	2.16	NS	0.40	0.38	NS	197	203	NS	0.29	0.14	5%	0.17	0.09	1%	0.10	0.10	NS	2.90	6.05	5%	0.01	0.79	5%	1.70	1.64	NS	1.40	0	1%	10.70	10.85	NS
sig	NS	NS		NS	NS		NS	NS		NS	5%		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	5%		NS	NS	
B. Idaho																																	
5931	0.78	2.08	1%	0.21	0.27	NS	437	165	1%	0.37	0.17	5%	0.12	0.10	1%	0.50	0.10	NS	3.20	0.80	1%	0.01	0.34	1%	2.04	1.55	5%	0.70	0.40	NS	15.80	12.70	NS
6000	2.22	1.80	1%	0.23	0.28	1%	131	144	NS	0.22	0.12	1%	0.09	0.08	1%	0.10	0.10	NS	2.40	4.60	1%	0.01	1.16	1%	1.67*	1.55	5%	0	0.20	1%	8.80	9.00	1%
9541	2.56	1.80	1%	0.25	0.28	1%	200	165	5%	0.29	0.19	5%	0.10	0.10	NS	0.20	0.50	NS	2.40	4.60	1%	0.01	1.24	1%	2.70*	2.01	1%	0.15	0.60	NS	13.55	10.60	NS
5986	2.04	1.74	5%	0.20	0.28	1%	210	198	NS	0.28	0.21	NS	0.09	0.08	1%	0.10	0.50	1%	3.05	6.40	1%	0.01	1.00	1%	2.07	2.01	NS	0	0.90	1%	27.45	18.10	NS
872	2.30	1.52	1%	0.25	0.23	NS	258	130	1%	0.44	0.25	5%	0.09	0.08	1%	1.30	0.80	NS	2.65	3.40	NS	0.01	0.59	1%	2.24	1.83	5%	0.45	1.30	NS	11.35	0.10	NS
sig	NS	5%		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	5%		NS	NS		5%*	NS		NS	NS		NS	NS	

NS = No Significance
* Significances between varieties 9541 and 6000

accumulation, but MSU 6000 was generally low. Many seasonal differences were noted in roots grown at the Idaho location, but neither growing season produced roots that were consistently high or low in mineral levels. Carrots grown in the 1972 season showed higher levels of potassium, sodium, calcium, magnesium, boron, and aluminum; whereas in the 1973 season they had higher phosphorous, iron, copper, and zinc levels.

Table 29 shows that there were no differences between locations in mineral accumulation. Samples from the Muck Farm location were generally higher in mineral accumulation, except for iron and aluminum where Texas samples were high, and copper where Idaho samples were high. MSU 6000 appears to be more sensitive to seasonal changes in mineral levels, just as it was for vitamin levels (Table 26).

Storage Time

It has been found that storage of carrot roots, even under optimum conditions, results in some changes in composition. Storage of roots for this study was maintained at optimum conditions and was held to a minimum.

Table 30 shows the storage time, in days, for each variety and location used in this study. Large variations in storage times occurred, especially between years. This may have contributed to some of the yearly differences found, particularly in those components which are susceptible to loss. Storage times within years are uniform for each location, thus no effect of storage time is indicated for those analyses.

Table 29. Parent Lines of Spartan Carrot Varieties, Mineral Levels by Variety at Four Locations

Location	%K 72	%K 73	sig	%P 72	%P 73	sig	Na mg/100g 72	Na mg/100g 73	sig	%Ca 72	%Ca 73	sig	%Mg 72	%Mg 73	sig	Mn mg/100g 72	Mn mg/100g 73	sig	Fe mg/100g 72	Fe mg/100g 73	sig	Cu mg/100g 72	Cu mg/100g 73	sig	B mg/100g 72	B mg/100g 73	sig	Zn mg/100g 72	Zn mg/100g 73	sig	Al mg/100g 72	Al mg/100g 73	sig
A. MSU 872																																	
Muk Fm E	—	3.30	—	—	0.49	—	—	158	—	—	0.25	—	—	0.14	—	—	1.90	—	—	5.05	—	—	0.88	—	—	2.52	—	—	2.50	—	—	8.45	—
Texas	3.05	2.24	NS	0.36	0.33	NS	251	241	NS	0.33	0.25	NS	0.17	0.15	NS	0.60	1.05	NS	2.80	3.75	NS	0.01	0.92	1%	2.24	2.10	NS	0.85	0.65	NS	13.25	9.00	NS
Idaho	2.30	1.52	1%	0.25	0.23	NS	257	130	1%	0.44	0.25	5%	0.09	0.08	1%	1.30	0.80	NS	2.65	3.40	NS	0.01	0.59	1%	2.24	1.83	5%	0.45	1.30	NS	11.35	0.10	NS
Muk Fm L	3.32	2.56	NS	0.46	0.45	NS	189	257	NS	0.40	0.28	NS	0.16	0.13	NS	0.52	0.60	NS	1.85	2.15	NS	0.61	0.54	NS	2.16	2.20	NS	0.90	0.85	NS	11.05	0.10	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. MSU 5931																																	
Muk Fm E	—	3.70	—	—	0.56	—	—	202	—	—	0.25	—	—	0.13	—	—	1.05	—	—	5.05	—	—	0.87	—	—	2.20	—	—	2.15	—	—	10.60	—
Texas	—	2.48	—	—	0.39	—	—	229	—	—	0.21	—	—	0.10	—	—	0.30	—	—	5.20	—	—	0.42	—	—	2.29	—	—	0.45	—	—	6.30	—
Idaho	0.78	2.08	1%	0.21	0.27	NS	437	165	1%	0.37	0.17	5%	0.12	0.10	1%	0.50	0.10	NS	3.20	10.80	1%	0.01	0.34	1%	2.04	1.55	5%	0.70	0.40	NS	15.80	12.70	NS
Muk Fm L	3.56	2.92	1%	0.51	0.52	NS	245	345	NS	0.42	0.29	NS	0.14	0.11	5%	0.47	0.45	NS	2.25	3.15	NS	0.36	0.42	NS	2.21	2.33	NS	1.42	1.30	NS	13.10	0.10	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
C. MSU 6000																																	
Muk Fm E	—	3.30	—	—	0.53	—	—	147	—	—	0.13	—	—	0.13	—	—	0.70	—	—	4.75	—	—	0.75	—	—	2.01	—	—	1.95	—	—	12.20	—
Texas	1.82	2.16	NS	0.40	0.38	NS	197	203	NS	0.29	0.14	5%	0.17	0.09	1%	0.10	0.10	NS	2.90	6.05	5%	0.01	0.79	5%	1.70	1.64	NS	1.40	0	1%	10.70	10.85	NS
Idaho	2.22	1.80	1%	0.23	0.28	1%	131	144	NS	0.22	0.12	1%	0.09	0.08	1%	0.10	0.10	NS	2.40	4.60	1%	0.01	1.16	1%	1.61	1.55	5%	0	0.20	1%	8.80	9.00	1%
Muk Fm L	3.10	2.56	NS	0.49	0.50	NS	118	140	NS	0.36	0.23	NS	0.13	0.13	NS	0.10	0.30	NS	1.57	2.75	NS	0.02	0.59	5%	1.84	1.92	NS	1.82	1.40	NS	5.87	0.10	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
D. MSU 9541																																	
Muk Fm E	—	3.45	—	—	0.50	—	—	228	—	—	0.23	—	—	0.18	—	—	1.75	—	—	5.50	—	—	0.84	—	—	2.84	—	—	2.20	—	—	11.35	—
Texas	3.67	3.01	NS	0.31	0.39	5%	221	229	NS	0.32	0.19	5%	0.17	0.14	NS	1.70	0.65	NS	3.65	4.60	5%	0.01	0.46	1%	2.77	2.61	NS	0.90	0.40	NS	17.05	3.20	NS
Idaho	2.56	1.80	1%	0.25	0.48	1%	200	165	5%	0.29	0.19	5%	0.10	0.10	NS	0.20	0.50	NS	2.40	4.60	1%	0.01	1.24	1%	2.70	2.01	1%	0.15	0.60	NS	13.55	10.60	NS
Muk Fm L	3.45	2.34	5%	0.45	0.49	NS	222	433	NS	0.32	0.23	NS	0.15	0.14	NS	0.15	0.30	NS	1.65	3.00	NS	0.01	1.20	NS	2.27	2.79	5%	0.65	1.20	NS	8.67	2.15	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
E. MSU 5986																																	
Muk Fm E	—	3.35	—	—	0.51	—	—	206	—	—	0.24	—	—	0.12	—	—	1.40	—	—	4.75	—	—	0.75	—	—	2.47	—	—	2.40	—	—	7.35	—
Texas	2.78	2.43	NS	0.43	0.33	5%	246	200	NS	0.29	0.17	NS	0.12	0.09	NS	0.10	0.45	NS	3.50	3.70	NS	0.01	0.34	NS	2.24	2.34	NS	0.15	0.45	NS	14.80	7.35	NS
Idaho	2.04	1.74	5%	0.20	0.28	1%	210	198	NS	0.28	0.21	NS	0.09	0.09	1%	0.10	0.50	1%	3.05	6.40	1%	0.01	1.00	1%	2.07	2.01	NS	0	0.90	1%	27.45	18.10	NS
Muk Fm L	4.02	2.19	5%	0.52	0.54	NS	226	484	1%	0.41	0.29	NS	0.12	0.13	1%	0.10	0.10	NS	2.40	3.70	5%	0.31	0.42	NS	2.36	2.47	NS	1.72	0.90	NS	14.50	0.10	NS
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	

NS = No Significance

Table 30. Root Storage Times, Days

Variety	Muk Fm E		Muk Fm L		Im Cty		Im Cty L		Texas		Idaho	
	72	73	72	73	72	73	72	73	72	73	72	73
Sweet	97	25	61	16	64	5	62	3	32	17	56	13
Fancy	--	25	62	15	69	5	62	2	32	17	55	13
Delite	--	25	62	15	64	5	63	3	31	17	56	13
Gold Pak	98	25	62	15	69	5	62	2	--	17	--	13
Bonus	--	25	61	15	--	-	--	-	31	17	57	13
Danvers	--	25	63	15	--	-	--	-	35	17	57	13
6000	--	26	60	16	--	-	--	-	32	16	58	13
872	--	26	57	16	--	-	--	-	36	16	57	14
5931	--	26	57	16	--	-	--	-	--	16	58	13
9541	--	26	60	17	--	-	--	-	36	16	58	14
5986	--	26	60	16	--	-	--	-	35	16	61	13

Analysis of Variance

The cause of significant differences between years can be surmised to be changes in the growing climate which influence the roots at different stages of growth. Within a given year, however, the environment is assumed to be equal for all roots at a given location. Differences between varieties and locations within a given year, then is dependent on other factors.

Although a few significant differences were found among varieties and locations, it was desirable to determine the source of the variations in the data. For this purpose a nested Least Squares Regression Analysis of Variance was run. Since storage time varied within years, this variable was included in the analysis as a covariate.

The chemical components were assigned as the dependent variables. Independent variables were assigned as variety, location, variety x location interaction, and storage time. By successively restricting each of the independent variables to zero, it was possible to determine what affect they had on the dependent variables.

The accomplishment of this analysis required the existence of a complete matrix, i.e., each combination of varieties and locations had to be complete with samples in each cell. Missing data, in both years, necessitated several analyses to encompass all varieties and locations. The results of these analyses are summarized in Table 31.

Table 31. Analysis of Variance Significance

Dependent Variable	Variety		Location		Variety x Location		Storage Time	
	72	73	72	73	72	73	72	73
Riboflavin				1%			1%	
Thiamin	1%	1%	1%	1%			1%	1%
Niacin		1%	1%	1%				
Ascorbic Acid	1%	1%		1%				1%
Total Carotenes	1%	1%	1%	1%		1%		1%
Beta Carotenes	1%	5%	1%	1%		1%		1%
Reducing Sugar		1%	1%	1%		1%		
Total Sugars	1%		1%	1%				5%
Soluble Solids		5%		1%		1%		1%
Total Solids				1%		5%		
Nitrogen		1%	1%	1%		1%		1%
K			1%	1%	1%	1%		
P		1%	1%	1%		1%		
Na	1%		1%	5%				5%
Ca			1%	1%				
Mg		1%		1%				
Mn			1%	1%				
Fe		1%	1%	1%				1%
Cu								
B	5%	5%	1%	1%				
Zn								
Al			1%	1%				1%
pH	5%	1%	1%	1%				5%

The significance levels shown in Table 31 are estimated over all of the analyses.

It is evident that the major factor which influenced the performance of a variety was the location where it was grown. This indicates that environment was the primary element that determined the nutritional composition of the carrot roots. The second most important influence on root nutrient accumulation was found to be varietal genotype. Interaction between variety and location was of less importance. Storage time, when maintained under conditions used in this study, did not seem to influence carrot composition to a great extent.

Combined Data for Varieties and Locations An Overview

This section was included to provide an overall look at the varieties and locations.

Table 32 shows the proximate and vitamin analysis results for the varieties. The values shown are average values of all locations where the variety was grown. As was seen in the previous section for Fresh Market Lines, no one fresh market variety stands out as being superior in composition. The nutrient levels attained were generally equal among the fresh market varieties.

The nutrient levels of the fresh market varieties were generally higher than those of the canning lines except in nitrogen, where the canning varieties were somewhat higher. Between the two canning varieties, Spartan Bonus had consistently higher nutrient levels than Danvers.

Table 32. Composition of Carrots, Proximate and Vitamin Analysis for Varieties

Variety	% Total Solids 72	73	Soluble Solids % 72	73	Reducing Sugars % 72	73	Total Sugars % 72	73	Nitrogen % 72	73	Carotenes mg/g Total 72	73	Beta 72	73	Riboflavin ug/g 72	73	Thiamin ug/g 72	73	Niacin ug/g 72	73	Ascorbic Acid mg/100g 72	73
A. Fresh Market Lines																						
Sweet	12.2	12.4	8.8	8.2	2.2	1.8	6.1	6.2	1.45	1.37	.19	.18	.18	.17	.76	.64	0.99	1.11	6.2	2.2	7.4	8.8
Fancy	12.6	12.7	8.7	8.8	2.2	2.1	6.1	6.5	1.38	1.36	.20	.20	.19	.18	.74	.66	1.15	1.28	5.9	2.4	9.6	9.2
Delite	12.7	12.6	9.0	8.6	2.0	1.4	6.2	6.2	1.39	1.33	.19	.19	.18	.17	.79	.68	0.99	1.11	6.8	2.3	8.5	11.2
Gold Pak	11.0	12.6	7.6	8.6	2.6	1.7	4.7	5.7	1.83	1.74	.18	.20	.17	.18	.75	.67	1.00	1.06	6.6	3.0	6.9	11.1
B. Canning Lines																						
Bonus	11.9	11.8	8.5	8.3	1.8	1.6	5.7	5.8	1.61	1.34	.18	.17	.16	.16	.69	.56	0.96	0.92	6.6	2.2	8.0	9.2
Danvers	11.0	11.3	7.8	7.8	2.2	2.6	5.4	5.4	1.46	1.23	.17	.16	.16	.14	.56	.47	0.84	0.93	5.7	2.1	6.1	7.8
C. Parent Lines																						
6000	13.9	13.0	9.8	9.0	2.7	2.4	7.1	6.4	1.37	1.38	.25	.23	.23	.21	.94	.83	1.28	1.66	6.3	2.8	10.4	11.0
872	12.1	12.5	9.1	8.5	2.2	2.1	6.2	6.0	1.44	1.47	.19	.20	.17	.18	.73	.71	0.79	0.76	5.5	2.5	6.4	7.5
5931	12.7	11.9	9.5	8.4	2.6	1.8	6.6	5.5	1.41	1.41	.15	.12	.15	.11	.58	.50	.89	1.00	7.3	2.6	7.6	10.5
9541	11.7	11.6	8.6	7.7	2.8	2.5	5.8	5.5	1.31	1.55	.20	.18	.19	.17	.69	.58	.78	.88	5.2	2.1	10.4	9.0
5986	12.4	12.2	8.7	7.9	2.0	2.2	5.6	5.9	1.39	1.40	.18	.18	.17	.17	.69	.59	1.26	1.19	5.3	2.5	9.5	9.1

Values shown represent average values for all locations.

Among the parent lines, MSU 6000 accumulated the highest levels of most nutrients, although it was consistently lowest in nitrogen level (Table 32). Performance of the other lines was relatively equal.

The findings of Booth and Dark (1949), that varieties maintain the same relative positions from year to year even though quantitative nutrient levels changed, could only be loosely applied to the fresh market varieties. The canning lines did support this work, however only two varieties were investigated. The parent lines also showed a relative consistency in order from one year to the next.

Table 33 contains proximate and vitamin values for roots grown at each of the locations. The values shown are average values of all varieties found at each location. The locations which provided samples in only one year of the study are also included for comparative purposes.

Carrots grown in Michigan accumulated higher levels of nutrients than carrots grown at the other locations. Samples from the Muck Farm locations in Michigan ranked high in nutrient accumulation. Neither early nor late planted roots showed consistent differences in nutrient levels.

The mineral composition of the varieties is shown in Table 34. The results follow the patterns of previous sections. No one fresh market variety showed higher mineral levels than the other fresh market varieties. Spartan Bonus was generally higher in minerals than Danvers, although Danvers did show higher levels of sodium, iron, and aluminum. MSU 6000 showed

Table 33. Composition of Carrots, Proximate and Vitamin Analyses for Locations

Location	% Total Solids		Soluble Solids %		Reducing Sugars %		Total Sugars %		Nitrogen %		Carotenes, m/g Total		Carotenes, m/g Beta		Riboflavin ug/g		Thiamin ug/g		Niacin ug/g		Ascorbic Acid ug/g	
	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73
Muk Fm E	9.7	13.3	6.3	8.2	2.8	4.1	4.1	5.7	1.71	1.64	.13	.19	.12	.18	.64	.80	0.68	1.23	6.4	3.2	5.7	12.0
Muk Fm L	13.2	11.9	9.4	7.3	2.6	0.7	5.8	5.3	1.88	1.85	.23	.23	.21	.21	.88	.66	1.24	1.57	7.3	2.8	8.7	7.1
Im Cty	11.6	11.8	8.1	8.1	1.7	0.6	5.3	5.6	1.48	1.44	.18	.17	.17	.16	.78	.68	0.78	1.14	8.5	2.8	5.0	12.3
Im Cty L	12.7	12.3	9.2	9.4	1.7	1.0	5.9	5.7	1.43	1.63	.23	.20	.21	.19	.70	.64	0.73	0.97	7.6	2.4	6.8	10.4
Texas	12.3	11.4	8.4	8.5	1.7	1.7	6.2	6.0	1.25	1.04	.17	.15	.16	.14	.57	.48	1.13	0.76	3.5	1.9	8.8	8.7
Idaho	12.3	12.5	9.1	9.1	2.7	1.9	6.8	6.8	0.93	0.99	.16	.14	.16	.13	.67	.50	0.70	0.79	6.3	1.5	9.2	10.1
Fremont	12.6	10.9	9.0	6.1	1.4	2.0	6.2	5.1	1.28	1.24	.23	.19	.21	.17	.77	.49	0.71	1.06	9.3	1.5	6.7	6.6
Florida	11.1	—	7.8	---	3.1	---	5.1	---	1.76	—	.17	---	.15	---	.79	---	1.46	—	3.4	---	7.2	—
Ohio	10.5	—	7.7	---	0.7	---	4.3	---	2.19	—	.17	---	.15	---	.63	---	0.80	--	6.1	---	6.7	—
Grant	--	12.8	---	9.7	---	1.8	---	6.3	—	1.63	---	.21	---	.19	---	.65	--	0.82	---	2.5	---	9.8
Mean	11.8	12.1	8.3	8.3	2.0	1.7	5.5	5.8	1.54	1.43	.18	.18	.17	.17	.71	.61	0.91	1.04	6.2	2.3	7.2	9.6

Values shown represent average values for all varieties at each location.

Table 34. Composition of Carrots, Mineral Analysis for Varieties, per 100g Dry Weight

Variety	%K		%P		Na mg/100g		%Ca		%Mg		Mn mg/100g		Fe mg/100g		Cu mg/100g		B mg/100g		Zn mg/100g		Al mg/100g	
	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73
A. Fresh Market Lines																						
Sweet	3.2	2.6	.46	.42	244	215	.26	.19	.12	.11	0.24	0.88	2.2	4.5	0.22	0.66	1.9	2.1	0.39	3.49	8.8	6.2
Fancy	2.8	2.4	.38	.41	183	212	.25	.18	.12	.10	0.50	0.54	2.1	3.8	0.21	0.65	1.9	2.0	0.57	0.87	8.8	5.6
Delite	3.1	2.6	.39	.40	178	247	.25	.18	.12	.11	0.54	0.67	2.1	4.6	0.25	0.64	1.9	2.1	0.92	1.13	7.6	9.6
Gold Pak	3.6	2.6	.51	.46	158	168	.31	.22	.16	.13	0.16	1.05	1.4	5.5	0.40	0.85	2.3	2.3	0.61	1.87	8.5	4.7
B. Canning Lines																						
Bonus	3.4	2.6	.46	.40	214	268	.35	.19	.15	.12	0.25	1.01	2.2	4.4	0.26	0.66	2.3	2.1	0.85	1.19	7.6	4.8
Danvers	3.3	2.4	.38	.35	245	313	.34	.24	.14	.11	0.14	0.92	2.3	4.5	0.16	0.95	2.1	2.1	0.67	1.42	8.8	8.3
C. Parent Lines																						
6000	2.4	2.4	.37	.42	149	159	.29	.16	.13	.11	0.10	0.30	2.3	4.5	0.02	0.82	1.7	1.8	1.08	0.89	8.5	8.0
872	2.9	2.4	.36	.37	232	197	.39	.12	.14	.12	0.81	1.09	2.4	3.6	0.21	0.73	2.2	2.2	0.73	1.32	11.9	4.4
5931	2.2	2.8	.36	.44	341	235	.39	.23	.13	.11	0.49	0.47	2.7	6.1	0.19	0.51	2.1	2.1	1.06	1.08	14.5	7.4
9541	3.2	2.6	.33	.41	214	264	.31	.21	.14	.14	0.68	0.80	2.6	4.4	0.01	0.94	2.6	2.6	0.57	1.10	13.1	6.8
5986	3.0	2.4	.38	.41	227	272	.33	.23	.11	.10	0.10	0.61	3.0	4.6	0.11	0.63	2.2	2.3	0.62	1.16	18.9	8.0

Values shown represent average values for all locations.

Table 35. Composition of Carrots, Mineral Analyses for Locations, per 100g Dry Weight

Location	%K		%P		Na mg/100g		%Ca		%Mg		Mn mg/100g		Fe mg/100g		Cu mg/100g		B mg/100g		Zn mg/100g		Al mg/100g	
	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73
Muk Fm E	3.3	3.2	.53	.51	261	172	.26	.23	.13	.14	0.10	1.27	1.8	5.6	0.55	0.86	2.2	2.3	0.93	2.31	6.9	11.0
Muk Fm L	3.7	2.4	.49	.47	197	326	.39	.24	.14	.13	0.26	0.40	2.1	3.3	0.24	0.80	2.2	2.3	1.28	2.58	8.0	0.7
Im Cty	3.5	2.9	.40	.48	225	318	.16	.17	.13	.13	0.14	1.46	1.8	6.2	0.60	0.70	2.0	2.5	0.60	2.48	15.9	16.3
Im Cty L	3.6	2.8	.44	.47	235	314	.38	.13	.13	.12	0.49	1.58	2.4	3.8	1.03	4.56	2.3	2.2	1.11	0.78	12.5	2.2
Texas	2.7	2.3	.35	.35	219	225	.33	.19	.14	.11	0.73	0.37	2.8	4.5	0.01	0.58	2.1	2.1	0.39	0.36	12.8	7.3
Idaho	2.0	1.8	.21	.27	207	155	.30	.17	.09	.08	0.44	0.25	2.5	4.5	0.01	0.64	2.0	1.7	0.24	0.47	11.7	6.5
Fremont	3.0	2.8	.36	.40	243	333	.26	.23	.13	.11	2.48	0.10	3.5	2.7	0.33	0.93	1.9	2.3	1.15	1.38	8.7	2.8
Florida	3.7	---	.63	---	156	---	.30	---	.13	---	0.19	--	0.2	---	0.33	--	1.9	---	0.19	---	0.6	--
Ohio	3.8	---	.58	---	217	---	.37	---	.20	---	5.04	--	2.4	---	0.30	--	2.5	---	1.00	---	10.6	---
Grant	---	2.9	---	.45	---	204	---	.10	---	.12	--	2.21	---	4.2	---	0.58	---	2.1	---	1.38	---	1.4
Mean	3.3	2.6	.44	.43	218	256	.31	.18	.14	.12	1.10	0.96	2.2	4.4	0.86	1.21	2.1	2.2	0.86	1.47	9.8	6.0

Values shown represent average values for all varieties at each location.

generally low mineral levels among the parent lines. No parent line showed consistently high mineral accumulation.

Mineral accumulation of the Muck Farm samples was generally high (Table 35). Exceptions to this would include manganese and copper. The late harvested samples from Imlay City showed high copper levels in both years of the study.

Canned Product

Analysis of canned carrots was undertaken as a preliminary phase of a future, more estensive investigation. For this reason vitamin analysis alone was accomplished on as many varieties as were available from previous canning experiments. Canned product was obtained from the 1971 and 1972 growing seasons. Varieties available consisted of Spartansweet (1971), Spartan Fancy (1971, 1972), Spartan Delite (1971, 1972), Spartan Delux (1972), Spartan Bonus (1971, 1972), and Danvers (1971, 1972). Physical can measurements were obtained and are shown in Table 36.

Table 36. Physical Measurements on Canned Products

Variety	Vacuum inches Hg		Total Wt. grams		Drained Weight grams	
	71	72	71	72	71	72
Sweet	5	--	485	---	310	---
Fancy	6	5	490	487	310	303
Delite	7	5	484	490	319	307
Delux	-	10	---	480	---	307
Bonus	6	5	490	485	310	301
Danvers	7	7	483	470	299	301

Fill weight 312 g

Table 37. Canned Product, Vitamin Assay

Variety	Riboflavin ug/g 71	72	sig	Thiamin ug/g 71	72	sig	Niacin ug/g 71	72	sig	Ascorbic Acid mg/100g 71	72	sig	Carotenes, mg/g Total 71	72	sig	Beta 71	72	sig
A. Can Solids																		
Sweet	.63	---	--	.54	---	--	2.88	--	--	3.62	--	--	.29	--	--	.26	--	--
Fancy	.35	.42	NS	.42	.93	NS	3.16	2.98	NS	3.41	3.46	NS	.25	.25	NS	.23	.23	NS
Delite	.34	.47	NS	.68	.80	NS	2.88	3.40	NS	3.38	3.51	NS	.22	.24	5%	.20	.22	NS
Delux	---	.37	--	---	.52	--	--	2.65	--	--	2.42	--	---	.18	--	---	.16	--
Bonus	.34	.34	NS	.43	.48	NS	2.39	2.47	NS	2.84	3.39	5%	.22	.23	NS	.20	.20	NS
Danvers	.33	.34	NS	.56	.54	NS	3.00	2.21	NS	3.50	1.83	5%	.26	.21	5%	.24	.19	1%
sig	NS	NS		NS	NS		NS	NS		NS	NS		NS	NS		NS	NS	
B. Can Liquid																		
Sweet	.34	---	--	.58	---	--	2.48	--	--	3.47	--	--						
Fancy	.32	.32	--	.47	.28	--	2.55	2.45	--	3.27	3.25	--						
Delite	.28	.34	--	.39	.21	--	2.16	2.40	--	2.47	3.62	--						
Delux	---	.27	--	---	.28	--	--	2.45	--	--	2.50	--						
Bonus	.28	.34	--	.65	.24	--	2.21	2.21	--	2.85	2.93	--						
Danvers	.26	.28	--	.68	.28	--	2.31	1.74	--	3.45	1.52	--						

Results adjusted to reflect fresh weight values.

NS = No Significance

Vitamin analysis results are shown in Table 37. There was generally no significance between years and there was no significance between varieties. Some significances may have appeared had more product been available. Limited product dictated that few replications could be run and, thus, higher critical values resulted. The results for the can liquids represent single replications so no statistical significances could be calculated. Carotene analysis was not run on the can liquids since carotene levels in the liquid are negligible.

Storage time for the cans was 2 years and 1 year for the 1971 and the 1972 seasons respectively. Equalization of the vitamins between the solids and the liquid was more complete in the 1971 products.

Comparing canned product with fresh root analysis shows that canning substantially reduces vitamin levels (Table 38). Carotene levels have seemingly increased in the canned product, however sample harvest dates and storage times were not the same for the canned and fresh roots. The canned roots were held for longer periods before canning than the fresh roots were held for analysis. Carotene accumulation during storage may explain higher canned results. If such is the case, carotene is shown to be most stable of the vitamins to canning. This would support the work of Weckel, et al. (1962) who reported a loss of approximately 10% of the pro-vitamin A activity through canning.

Table 38. Vitamins of Canned vs. Fresh Roots, 1972 Season

		Variety:	Fancy	Delite	Bonus	Danvers
Riboflavin ug/g		can	0.42	0.47	0.34	0.34
		fresh	0.74	0.79	0.69	0.56
Thiamin ug/g		can	0.42	0.68	0.43	0.56
		fresh	1.15	0.99	0.96	0.84
Niacin ug/g		can	3.2	2.9	2.4	3.0
		fresh	5.9	6.8	6.6	5.7
Ascorbic Acid mg/100g		can	3.4	3.4	2.8	3.5
		fresh	9.6	8.5	8.0	6.1
Carotenes mg/g	Total	can	0.25	0.22	0.22	0.26
		fresh	0.20	0.19	0.18	0.17
	Beta	can	0.23	0.20	0.20	0.24
		fresh	0.19	0.18	0.16	0.16

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the nutritional composition of several varieties and hybrids of carrot roots. The hybrids used were developed at Michigan State University from inbred parent lines. The parent lines from which the hybrids were derived were also included for comparative purposes. Two unrelated, longer established, carrot varieties were analyzed with the MSU varieties so that relative performance of the MSU varieties could be judged.

Twelve carrot varieties and lines were investigated. These were divided into three groups in accordance with varietal type. Fresh Market types included Spartansweet, Spartan Delite, Spartan Fancy, Spartan Delux and Gold Pak. Two canning types were used which were Spartan Bonus and Danvers. The Parent Lines group consisted of the inbred lines used to produce the Spartan varieties.

Sample roots were grown at several locations to determine if growth locations had a great influence on varietal performance. The major locations which contributed to this study were the MSU Muck Farm; Imlay City, Michigan; a location in Texas; and a location in Idaho. Additionally, roots were obtained from Fremont, Michigan; Grant, Michigan; Ohio; and Florida.

It was believed at the beginning of this study that great differences in nutritional composition would occur between

growth locations and among varieties. The results obtained did not entirely prove this premise to be true. While some significant differences were found between varieties, virtually no differences were found between locations. The varietal differences were random and not consistent. Although significant differences were scarce, some trends did emerge which are of interest.

The results varied a great deal between the two growing seasons. This indicates that climatic conditions and environment are very important in nutrient accumulation. This is not a new concept and has been shown by various other workers.

No one variety among the Fresh Market Lines stood out as being superior in accumulation of nutritional components. Variations did occur between years, locations, and varieties but no variety was consistently high in any component.

Between the Canning varieties, Spartan Bonus emerged as the superior variety. Spartan Bonus had consistently higher levels of all components but nitrogen.

Among the Parent Lines, MSU 6000 appeared to be the best for nutritional composition. MSU 6000 showed consistently high levels of vitamins and proximate components. Mineral response was relatively equal among all of the parent lines.

Among the locations, it seemed the Muck Farm was generally better than the other locations for production of nutritional components. Values were generally high in the Muck Farm samples although no preference for either early or late planting was evident. The pH values of the early planted

samples from the Muck Farm were consistently lowest among the locations. The Idaho location produced generally higher sugar levels than the other locations.

It would be desirable from a production standpoint to grow roots at a location that maintained relative consistency in root composition from year to year. In this respect, the late planted samples from the Muck Farm exhibited better stability from season to season than the other locations. Additionally, it would be desirable from a production standpoint to obtain a variety that showed relative seasonal stability, and to discard those varieties that greatly varied from year to year. This study indicated a relatively constant stability among the varieties with two exceptions. The Fresh market variety Spartansweet, showed greater seasonal instability than the other varieties. The parent line MSU 6000 showed seasonal instability in vitamin production. It is interesting to note that Spartansweet has MSU 6000 as one parent, the other being MSU 5931. It may appear, then, that stability of nutritional components is a heritable trait that can be introduced into new varieties.

Analysis of variance showed that locations and variety contributed most to variation in results within growing seasons. Variety x location interaction affects contributed to some variation and storage time showed little influence on results.

A preliminary vitamin analysis on canned product showed that canning greatly reduces vitamin levels. The carotenes were the least depleted but measurement of quantitative levels was not possible between fresh and canned product.

The findings of this work generally support the reports of previous researchers.

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APPENDIX

Table 39. 1972 Results, Fremont, Michigan

Variety	pH	Nitrogen %	Reducing Sugars %	Total Sugars %	Soluble Solids %	Total Solids %	Riboflavin ug/g	Thiamin ug/g	Niacin ug/g	Ascorbic Acid mg/100g	Carotenes mg/g Total	Carotenes mg/g Beta
Sweet	6.02	1.36	1.05	6.68	9.40	13.02	.87	.87	8.10	6.40	.23	.21
Fancy	6.05	1.19	1.57	6.29	9.38	13.43	.73	.83	11.38	8.72	.26	.24
Delite	6.03	1.33	1.07	7.12	10.12	13.81	.91	.80	9.61	7.08	.22	.21
Delux	6.10	1.25	1.33	6.21	8.95	12.40	.89	.68	10.08	5.35	.24	.22
Bonus	6.07	1.30	1.04	5.86	8.57	12.16	.61	.53	9.81	6.96	.21	.19
Danvers	6.11	1.22	2.09	5.34	7.82	10.73	.63	.56	6.99	5.99	.22	.20

Variety	%K	%P	Na mg/100g	%Ca	%Mg	Mn mg/100g	Fe mg/100g	Cu mg/100g	B mg/100g	Zn mg/100g	Al mg/100g
Sweet	2.8	.35	263	.26	.12	0.95	2.87	.04	1.8	0.7	5.0
Fancy	2.9	.35	208	.23	.14	2.27	3.95	.31	2.0	1.2	9.1
Delite	2.8	.35	235	.20	.13	2.27	3.80	.23	1.6	1.2	14.4
Delux	3.3	.37	230	.25	.14	2.15	3.95	.20	1.9	1.2	8.7
Bonus	3.1	.41	246	.29	.13	3.90	3.27	.54	2.1	1.4	7.9
Danvers	3.0	.32	276	.32	.12	3.32	3.12	.64	2.1	1.0	7.2

Table 40. 1972 Results, Ohio and MSU Muck Farm, Late Planting, Late Harvest

Variety	pH	Nitrogen %	Reducing Sugars %	Total Sugars %	Soluble Solids %	Total Solids %	Riboflavin ug/g	Thiamin ug/g	Niacin ug/g	Ascorbic Acid mg/100g	Carotenes mg/g Total	Carotenes mg/g Beta
A. Ohio												
Bonus	5.99	2.32	.70	3.8	7.95	10.68	.62	.76	6.82	7.39	.17	.15
Danvers	6.00	2.06	.73	4.7	7.42	10.39	.65	.83	5.32	5.92	.17	.15
B. Muck Farm, Late Planting, Late Harvest												
Sweet	6.08	1.97	1.57	4.98	8.80	11.13	.70	1.42	7.32	5.38	.21	.20
Fancy	6.00	2.02	0.65	4.40	8.55	11.35	.66	1.94	6.12	5.69	.22	.20
Delite	6.17	1.75	2.17	5.32	9.00	11.91	.70	1.80	7.38	7.94	.21	.19
Delux	6.13	2.10	1.62	4.88	9.05	11.36	.73	1.42	9.97	4.19	.20	.22
Bonus	6.08	1.84	2.13	5.14	8.45	12.16	.59	1.06	8.42	8.10	.21	.19

Variety	%K	%P	Na mg/100g	%Ca	%Mg	Mn mg/100g	Fe mg/100g	Cu mg/100g	B mg/100g	Zn mg/100g	Al mg/100g
A. Ohio											
Bonus	4.2	.61	207	.36	.20	7.17	3.02	.47	2.5	0.9	8.1
Danvers	3.4	.56	227	.38	.20	2.90	1.72	.13	2.4	1.1	13.2
B. Muck Farm, Late Planting, Late Harvest											
Sweet	3.6	.52	254	.34	.16	0.10	1.80	0.04	2.1	0.7	6.9
Fancy	3.3	.46	199	.39	.13	0.10	1.65	0.01	2.3	0.6	3.5
Delite	3.8	.48	160	.30	.11	0.10	1.20	0.01	2.4	0.8	6.0
Delux	3.1	.55	221	.36	.13	0.10	1.80	0.01	2.4	0.2	11.3
Bonus	4.0	.60	231	.39	.16	0.20	1.05	0.08	2.6	1.1	6.3

Table 41. 1972 Results, Florida

Variety	pH	Nitrogen %	Reducing Sugars %	Total Sugars %	Soluble Solids %	Total Solids %	Riboflavin ug/g	Thiamin ug/g	Niacin ug/g	Ascorbic Acid mg/100g	Carotenes mg/g Total	Carotenes mg/g Beta
Sweet	5.85	1.72	3.38	4.80	7.70	10.69	.79	1.31	3.32	6.68	.18	.17
Fancy	6.15	1.58	3.74	5.95	8.50	12.03	.87	1.83	2.88	10.54	.20	.18
Delite	6.10	1.59	3.70	5.35	8.20	11.55	.86	1.58	3.95	8.09	.17	.15
Delux	6.07	1.75	2.70	5.02	7.85	11.02	.84	1.59	2.54	6.37	.17	.15
Gold Pak	6.00	1.91	3.00	4.92	7.30	10.86	.75	1.51	3.82	6.11	.16	.15
Bonus	6.07	1.99	2.21	5.10	8.40	11.61	.86	1.59	4.35	6.35	.17	.15

Variety	%k	%P	Na mg/100g	%Ca	%Mg	Mn mg/100g	Fe mg/100g	Cu mg/100g	B mg/100g	Zn mg/100g	Al mg/100g
Sweet	4.1	.69	147	.39	.13	0.10	0.20	0.43	1.9	0.3	1.5
Fancy	3.4	.56	163	.16	.11	0.10	0.10	0.01	1.6	0	0.1
Delite	4.6	.66	130	.25	.13	0.10	0.20	0.08	2.1	0	0.1
Delux	3.7	.63	131	.28	.13	0.10	0.10	0.01	1.7	0	0.1
Gold Pak	3.3	.61	87	.40	.16	0.35	0.35	1.02	2.3	0.5	0.9
Bonus	3.7	.73	127	.32	.20	0.10	0.10	0.26	2.6	0.2	0.6

Table 42. 1973 Results, Spartan Bonus at Imlay City, Imlay City, Late Harvest and Fremont Locations

Location	pH	Nitrogen %	Reducing Sugars %	Total Sugars %	Soluble Solids %	Total Solids %	Riboflavin ug/g	Thiamin ug/g	Niacin ug/g	Ascorbic Acid mg/100g	Carotenes mg/g Total	Carotenes mg/g Beta
Im Cty	5.84	1.52	0.49	5.47	7.95	12.01	.66	1.15	2.48	10.18	.16	.15
Im Cty L	5.87	1.53	1.16	5.77	8.78	12.25	.67	0.62	2.76	11.41	.20	.16
Fremont	6.25	1.05	1.44	4.80	6.60	9.46	.38	1.30	1.36	7.53	.16	.15

Location	%K	%P	Na mg/100g	%Ca	%Mg	Mn mg/100g	Fe mg/100g	Cu mg/100g	B mg/100g	Zn mg/100g	Al mg/100g
Im Cty	2.9	.49	331	.21	.13	1.90	6.95	.75	2.5	2.6	18.6
Im Cty L	2.6	.45	234	.13	.14	1.10	3.30	.34	2.2	0.4	1.8
Fremont	2.7	.32	494	.24	.09	0.10	3.05	.71	2.2	1.1	1.1

Table 43. 1972 Results, Grant, Michigan Samples

Variety	pH	Nitrogen %	Reducing Sugars %	Total Sugars %	Soluble Solids %	Total Solids %	Riboflavin ug/g	Thiamin ug/g	Niacin ug/g	Ascorbic Acid mg/100g	Carotenes mg/g Total	Carotenes mg/g Beta
Sweet	5.95	1.67	2.21	6.79	10.35	13.22	.60	1.20	2.51	8.93	.22	.20
Fancy	6.05	1.47	2.32	7.61	11.40	13.42	.90	1.02	2.48	8.16	.24	.21
Delite	5.95	1.61	1.31	6.60	10.07	13.21	.74	1.07	2.82	10.86	.23	.20
Gold Pak	5.90	2.30	1.87	5.06	8.92	11.73	.75	0.62	3.22	8.10	.19	.17
Bonus	6.03	1.46	1.33	6.11	9.15	12.47	.70	0.68	2.77	9.24	.19	.18

Variety	%K	%P	Na mg/100g	%Ca	%Mg	Mn mg/100g	Fe mg/100g	Cu mg/100g	B mg/100g	Zn mg/100g	Al mg/100g
Sweet	2.8	.46	177	.11	.11	1.75	4.15	0.55	2.1	0.9	1.8
Fancy	2.6	.40	232	.09	.11	1.80	3.40	0.54	2.1	1.1	1.3
Delite	2.9	.46	221	.09	.11	1.05	3.15	0.50	2.1	0.8	1.5
Gold Pak	3.1	.52	185	.17	.15	2.45	5.20	1.08	2.7	2.6	2.3
Bonus	3.0	.43	154	.10	.10	3.70	4.75	0.67	1.9	1.7	1.0